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Program. Volume 1

GCA Corp., Bedford, MA. GCA Technology Div.

Prepared for

Environmental Monitoring System Lab.
Research Triangle Park, NC

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16. ABSTRACT

This report summarizes the prime contractor activities during the monitoring phase of the Love Canal project. Since GCA Corporation was only responsible for data collection, no analytical results appear in this report. The program involved a multifaceted sampling and analytical effort designed to detect and quantify a variety of trace metals,* volatile organics, pesticides and other compounds in soil, sediment, air, biota, and water samples. The principal purpose of these activities was to provide data with which EPA could assess the extent of environmental contamination in the Love Canal Area. Since the area declared as a National Emergency was extended from those homes directly surrounding the Love Canal dumpsite to a more general area on May 21, 1980, it had been determined that the overall exposure of residents must be established as quickly as possible. The program, therefore, was on an extremely tight schedule with field sampling activities to be completed by October 31, 1980.

GCA organized its efforts into seven technical elements, each of which is discussed.

17. KEY WORDS AND DOCUMENT ANALYSIS

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# LOVE CANAL MONITORING PROGRAM--FINAL REPORT: Volume 1

by

GCA Corporation
GCA/Technology Division
Bedford, MA 01730

EPA Contract 68-02-3168

EPA Project Officer
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## SECTION 1

## INTRODUCTION

The purpose of the Love Canal Monitoring Program was to evaluate pollutant levels present in the Love Canal Area of Niagara Falls, New York. Environmental Monitoring Systems Laboratory (EMSL)/Las Vegas, Environmental Monitoring Systems Laboratory (EMSL)/Research Triangle Park, Environmental Monitoring and Support Laboratory (EMSL)/Cincinnati, Health Effects Research Laboratory (HERL)/Research Triangle Park, and the Robert S. Kerr Environmental Research Laboratory, (ERL)/Ada, Oklahoma, collaborated on the design of the study with EMSL/RTP assigned as the coordinating EPA laboratory. Events surrounding the Love Canal situation during the early summer of 1980 made the timely completion of the entire monitoring program of highest importance within the Agency. Accordingly, GCA/Technology Division was issued a task on July 9, 1980 to assist EPA in successfully completing the Love Canal Monitoring Program within a very restrictive time frame. GCA was charged with the responsibility of managing the program and ensuring its timely completion in a technically acceptable manner through the use of selected subcontractors. Each of the EPA laboratories was to maintain a high level of involvement throughout the program, providing technical advice, undertaking quality control activities, and determining the validity of the data generated.

The program involved a multifaceted sampling and analytical effort designed to detect and quantify a variety of trace metals,* volatile organics, pesticides and other compounds in soil, sediment, air, biota, and water samples. The principal purpose of these activities was to provide data with which EPA could assess the extent of environmental contamination in the Love Canal Area. Since the area declared as a National Emergency was extended from those homes directly surrounding the Love Canal dump site to a more general area on May 21, 1980, it had been determined that the overall exposure of residents must be established as quickly as possible. The program, therefore, was on an extremely tight schedule with field sampling activities to be completed by October 31, 1980.

GCA organized its efforts into seven technical elements as shown in Figure 1.1, Project Organization Chart. Although the various EPA laboratories had designed the overall study and provided detailed protocols for many of the

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*Refer to Appendix A (pp. A-2) for compound hit lists and explanation of terms used for compound classes.

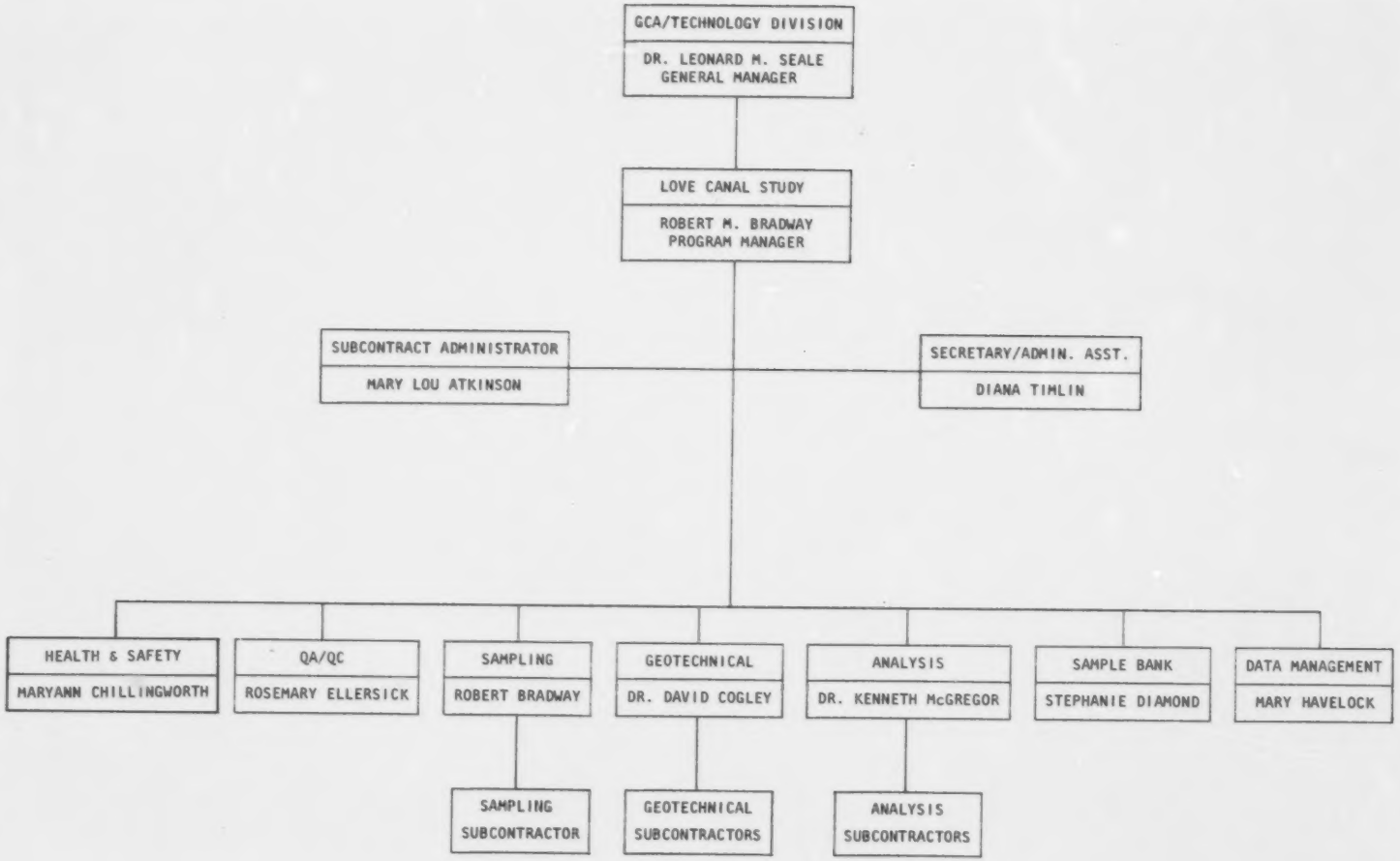


Figure 1.1. GCA project organization and responsibility.

program elements, it was GCA's responsibility to coordinate and implement these procedures into a manageable system. The following paragraphs very briefly describe the activities undertaken by GCA in each of the seven program elements.

HEALTH AND SAFETY

A comprehensive safety and health plan was developed which specified procedures to help protect all personnel engaged in the Love Canal Monitoring Project. The complexity and variety of chemical agents thought to be present at the Love Canal made it necessary to design a highly flexible yet conservative program of worker protection. The advice of consultants was sought in the design of this program, and safety and health guidelines provided by the Federal Government and the State of New York were incorporated.

The basic elements of the safety and health program consisted of a preassignment medical examination of each employee who was engaged in sampling in the field or in the handling of samples in the field prior to their shipment to subcontractor laboratories. The medical examinations and subsequent consulting services were provided by physicians who are Board-certified in industrial medicine.

Individuals involved in field sampling activities were trained in the use of safety and protective gear appropriate to the activity. GCA provided two industrial hygienists, and the sampling subcontractor, Geomet Technologies, Inc., also provided two industrial hygienists to review and monitor procedures and sampling activities at the Love Canal site. The Geomet industrial hygienists were on site during any sampling activities. A series of Safety and Health Directives were issued to address procedures to be followed during the several sampling activities. Review of laboratory safety procedures in force in the subcontractors' laboratories was made to ensure that the levels of protection provided were consistent with the hazards potentially present in the samples they analyzed.

SAMPLING

The overall program design and the specific sampling protocols had been developed by EPA. It was GCA's responsibility to acquire via competitive bids a qualified subcontractor to collect the multimedia samples for subsequent analysis for volatile organics, semivolatile organics, pesticides, inorganics and radioactivity.

Air samples were collected in the living areas of homes, in basements and outdoors using Tenax, polyurethane foam (PUF) and hi-vols. Water samples were collected from drinking water supplies, sewers, basement sumps, rivers, streams and ground water monitoring wells. Soil and sediment samples were collected throughout the study area. A biota sampling campaign also resulted in the collection of animals and plant materials.

GCA managed the sampling activities from a field office established in a vacant home in the immediate vicinity of Love Canal. This office, staffed with knowledgeable technical personnel and support/secretarial capabilities,

served as the communications center for all field activities. All individuals involved with the field operations were required to report to the field office at the beginning and end of each day, not only as a management control but also to ensure that the latest technical and safety directives were given to all affected parties.

ANALYSIS

As with sample collection, the analytical protocols were provided by EPA. GCA had to procure via competitive bids the appropriate number of subcontractor laboratories to provide the analysis of the collected samples. In addition, subcontractor laboratory services were procured for the preparation of the Tenax and PUF cartridges and the preparation of Tenax cartridge standards and spikes used in the air monitoring program. The HERL/RTP prepared the QC standards and spikes for the PUF cartridges.

Tenax samples were analyzed for volatile organic compounds; PUFs were analyzed for pesticides and related compounds, and hi-vol filters were analyzed for metals. Specific compounds and elements of these groups are listed in Appendix A to this report.

The various types of water samples were analyzed for volatile organics, semivolatile organics, pesticides, metals, and the anions fluoride and nitrate. Ground water samples were also analyzed for total organic carbon (TOC) and total organic halides (TOX). The pH and conductivity of ground water samples were also measured.

Soil and sediment samples were also analyzed for volatile organics, semivolatile organics, pesticides and metals. Anions, TOC and TOX were not measured in these sample types. Because no widely-accepted methods existed for the analysis of semivolatiles in these media, a methods evaluation was conducted on 48 samples to determine which of three available procedures was most suitable. The analytical subcontractors used the method determined by this study for the remainder of the program.

Various biota samples were analyzed for organic and inorganic species on the Love Canal Monitoring List. Biological materials, specifically mice, worms, and crayfish were analyzed for semivolatile organics and pesticides. Potatoes and oatmeal placed at the sampling sites were designated as "foodstuffs" and analyzed for volatile organic compounds. Metals were measured in vegetation and in hair.

GEOTECHNICAL

The geotechnical portion of the Love Canal Study was designed principally by the EPA's Robert S. Kerr Laboratory in Ada, Oklahoma. It consisted of the following three activities:

- Geophysical measurements such as ground penetrating radar, electromagnetic conductivity and magnetometry to determine subsurface characteristics.

- Hydrogeological investigation which consisted of the installation of 174 monitoring wells.

- Ground water modeling which predicted the movement in each aquifer.

GCA's responsibility was to obtain the necessary subcontractor skills via competitive bids and to ensure the timely completion of the work. There were Ada staff on site to provide technical advice during the field program.

SAMPLE BANK

The sample bank was set up and staffed with GCA personnel during the field program. The purpose of the sample bank was to oversee all aspects of sample handling, chain of custody procedures and document control. The Sample Bank Manager served as GCA's Document Control officer onsite and directed the following activities:

- dispensing custody records

- receiving precleaned air collection media

- receiving external QC samples and calibration standards

- dispensing sample tags

- receiving collected samples

- verifying custody record against collected sample before accepting custody

- logging accepted samples into Master Log

- maintaining internal custody of samples while in the Sample Bank

- maintaining document control of sample tags and custody records

- regrouping collected samples for shipment to analytical labs

- inserting external QC samples into the analytical shipments

- packing samples appropriately for shipment

- transferring custody of the sample shipment to the carrier

- notifying the analytical laboratory of shipment

The selected Sample Bank facilities were appropriate for this multifaceted operation; they included a 400 square foot shipping and receiving area, 1,240 square feet of fully equipped laboratory space, and 230 square

feet of office space at the Bell Aerospace Textron plant in Niagara Falls, New York. A 35-foot refrigerated trailer was placed adjacent to the entrance to provide 245 square feet of refrigerated storage area at the Bank; a refrigerated truck was also leased to transport samples from their collection area to the Bank and from the Bank to Buffalo Airport for shipment to analytical laboratories.

The laboratory area included two 6-foot fume hoods, sinks, refrigerators, a freezer, and adequate bench space. The air handling system was modified to ensure 100 percent fresh air intake and no air return through the system to avoid contamination of collected samples. The office area included standard office furnishings and a copying machine.

The entire area, including the refrigerated trailer, had access restricted to GCA employees with keys; it was accessible 24 hours a day, 7 days a week. Bell Aerospace security guards maintained security of the whole complex at all times. The file cabinets and storage containers for documents and samples were equipped with security bars and combination locks.

QA/QC

The objective of the GCA/Technology Division contract efforts on this program was to collect representative multimedia samples which could then be analyzed in the required time frame and by the best available methods. In a sense, most of GCA's work on the Love Canal Study was quality assurance--managing so as to achieve high quality results.

An important objective of the quality program was to alert the subcontractors to the importance of high quality work on their part and to demonstrate continuing concern for quality throughout the program. Measures taken by GCA to accomplish this included the provision of: general QA/QC requirements in the Requests for Proposal (RFP) for all technical work to be subcontracted; EPA's specific internal QC requirements in each analytical subcontract document; the requirement for subcontractor QA Plans; QC Coordinators with expertise in each technical area; written sampling and analysis procedures including QC requirements and planned corrective actions; Performance Evaluation and QC check samples for analytical work and, perhaps most important, continuing communication between GCA and its subcontractors.

The QA goals of the program were stated as follows:

- Collect Representative Samples
- Maintain Chain of Custody of Samples
- Analyze Samples using Appropriate Procedures
- Achieve Comparable Results from Different Analytical Laboratories

- Estimate Precision and Accuracy Achieved
- Manage and Store Sampling and Analysis Data Generated
- Report Analytical Results in a Useable Format
- Compile a Complete Project Document Inventory

A comprehensive four volume quality assurance plan was written and then implemented by GCA in pursuit of the above stated goals and objectives.

The remainder of this report is organized around the seven program elements just mentioned. Each succeeding section amplifies the activities undertaken by GCA within these elements with much of the documentation being provided as appendices. It should be noted that GCA has provided documentation on several aspects of the Love Canal Monitoring Program in previous submittals.* Generally, information presented in these earlier documents, such as detailed sampling and analytical procedures, will not be included in this summary report. However, program elements that have not to date been documented in formal reports (e.g., Data Management System) will be discussed in considerable detail in this Final Report.

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*Previous submittals include the following documents: Quality Assurance Plan, Love Canal Study; QA Plan Appendix A, Sampling Procedures; QA Plan Appendix B, Analytical Procedures; QA Plan Appendix Q, Subcontractor QA Plans; and Love Canal Study, QA/QC Summary Report, January 1982.

## SECTION 2

## HEALTH AND SAFETY

GCA was responsible for developing a health and safety plan both for its own employees as well as providing minimum standards that each subcontractor had to meet. Protocols were established covering field operations and laboratory operations. Extensive use was made of the following documents in preparing the Plan.

- "Enforcement Considerations for Evaluations of Uncontrolled Hazardous Waste Disposal Sites by Contractors," National Enforcement Investigations Center (NEIC), U.S. EPA, April 1980.
- "Safety Manual for Hazardous Waste Site Investigations," U.S. EPA, September 1979.
- "Safety Plan, Procedures to be Observed During the Collection of Soil Samples at the Love Canal Chemical Waste Dump," New York State Department of Health.

The plan incorporated the rules, guidelines and recommended work practices contained in the above-referenced material. All project personnel were expected to follow the safety and health procedures set forth, referring to the appended material for background information. In the event of doubt or ambiguity, supervisors were to contact the GCA Safety and Health Officer for resolution before proceeding.

It is clearly impossible to anticipate all specific safety and health hazards beforehand so all field and laboratory personnel must exercise common sense and good judgment in their approach to a given situation. Expert advice on these matters was available to all personnel through the Safety and Health Officer, and through GCA's medical consultants.

Highlights of the Safety and Health program for the Love Canal Study included:

- Consulting services of a physician with a specialty in occupational medicine, were available through GCA/Technology Division.
- Field personnel underwent a physical examination both before and after the field sampling phase of the Love Canal Project.

- All field personnel who entered the Love Canal Site and who collected or handled environmental samples participated in a training program in the use of respirators, protective gear and in specific safety procedures to be followed.

- As the various phases of the Sampling Tasks progressed, Safety and Health Directives were issued at the GCA Office located at the Love Canal Study Area, Colvin Boulevard, Niagara Falls, New York. A copy of these Directives and any additions were issued to each GCA staff member and to each member of the subcontractor teams at the beginning of each day's work when that member signed-in at the GCA Field Office.

- An Industrial Hygienist was on call at all times during sampling activities at the Love Canal Site. Any questions that arose concerning potential exposures to toxic vapors or other chemical agents were directed to him. Any deviations from Safety and Health procedures contained in the onsite Directives had to be cleared through the Industrial Hygienist beforehand.

- Local Emergency Services (Fire Department, Hospital) were advised of the sampling activities at the Love Canal Site and they were prepared to deal with helath-related emergencies.

- If flammable materials were encountered during any sampling operations, the local Fire Department was to be contacted immediately.

- Each drill rig was equipped with a Fire Extinguisher (10 lb, for Class A, B, C fires), a First Aid kit and a portable eye wash station.

The following paragraphs, excerpted from the Health and Safety Plan describe some of the important features.

MEDICAL SCREENING

All personnel who will be collecting, or handling or analyzing samples obtained from the Love Canal Study Area must undergo a medical evaluation before participating in the study and again at its conclusion. The purpose of the medical screening program is fourfold:

- Assessment of health status of personnel prior to work.

- Support of health of personnel during project.

- Evaluation and care of personnel in the event of a work-related accident or illness.

- Monitoring of personnel for evidence of post-study adverse health effects and determination of their suitability for future work assignments of this type.

## Assessment of Health Status of Personnel Prior to Work

The preassignment medical examination will:

- Evaluate physical and psychological suitability of the worker for the proposed work.
- Identify health factors which may disqualify or restrict a worker from specific tasks under the project.
- Assess capability of candidate worker to wear the required protective gear.
- Determine baseline or reference data to help evaluate the significance of findings that may appear during subsequent medical examination.

The details of the examination are left to the discretion of the examining physician but should consist of a medical and occupational history, a thorough physical examination with particular attention to the cardiopulmonary systems, general physical fitness, skin, blood forming, hepatic, renal and nervous systems. Tests should include chest x-ray, electrocardiogram, ventilatory pulmonary function, urinalysis, a complete blood count, liver function and a blood chemistry profile. Additional tests and procedures may be indicated in the judgment of the examining physician, based on knowledge of the work to be performed.

Copies of all medical reports associated with the Love Canal Study Project must be provided to the prime contractor. These medical records will be held in strict confidence by GCA and will not be released to anyone without the written permission of the individual.

## Support of Health of Personnel During Project

During the project the following will be provided by the prime contractor:

- First Aid equipment will be maintained at the GCA Field Office and Emergency Medical Services (Fire Department, Police Department and local Hospital) will be notified of activities at the Love Canal Site.
- An Emergency Transport Plan will be explained to all field personnel during the Training Session.
- A Medical Consultant with a specialty in occupational medicine will be available for consultation at the Love Canal Site should health problems arise during the course of sample collection and handling.
- An Industrial Hygienist Consultant will establish specific procedures to be followed for each sample collection and handling activity. Services will also be available to monitor any suspect area for toxic chemical agents during the study.

Evaluation and Care of Personnel in the Event of a Work-Related Accident or Illness

Emergency medical care will be provided through a local hospital under consultation with the Medical Consultant assigned to this project. The local Poison Control Center will also provide services as required.

Monitoring of Personnel for Evidence of Post-Study Adverse Health Effects and Determination of Their Suitability for Future Work Assignments of this Type

The purpose of post-study medical monitoring will be to:

- Assist in early detection of work-related health effects (from this study and others that may be undertaken in the future) in project personnel.

- Assess the health status of project personnel as to fitness and suitability for future assignments of this nature.

Copies of the post-study medical examinations must be provided to the prime contractor's medical consultant for recordkeeping purposes. These medical records will be held in strict confidence by GCA and will not be released to anyone without the written permission of the involved party.

SAFETY AND HEALTH TRAINING

Field Personnel Training

Before beginning work at the Love Canal Study Area, each field team member must attend a Safety and Health Training Program. The Training Sessions will be given at or near the Love Canal Site. Each session will be approximately 1 day in length and will be conducted by a staff trained in industrial hygiene and safety. Topics to be discussed will include:

1. Purpose of Training:

   - Ensure that regard for the health and safety of the employees of other agencies, the public, and the environment is maximum.

   - To comply with all laws, rules, and regulations to safeguard the health and safety of all employees, the public, and the environment.

   - Increase the ability of employees to react responsibly and to handle emergency situations in a safe manner.

2. General Field Safety Techniques:

   - Availability of safety and health Consulting Services (medical, Industrial Hygiene) and when and how to use them.

- Responsibilities
  - Site surveillance/observation/plan development,
  - Restricted zones,
  - Safe zones,
- Vehicles (cars, trucks, drill rigs)
  - Inspection,
  - Operation,
  - Mandatory rules, regulations, and orientation,
  - Decontamination.
- Hazardous Materials in the Field
  - Hazards,
  - Storage,
  - Transportation (DOT requirements for common sample preservatives, plus general "common sense" rules).
- Use of Field Equipment and Supplies
  - Work Tools,
  - Testing Equipment,
  - Sampling Equipment,
- Working Practices
  - Working Alone (buddy system)
  - Isolated Areas,
  - Streams, Rivers, Lakes,
  - Hazardous Waste Sites.
- Work Limitations
  - Prohibited Work Practices,
  - Fatigue,
  - Hours of Work.

3. Personal Protective Equipment and Clothing:

- Respiratory Protection,
- Selection,
- Fit,
- Donning and Use.
- Personal Protection Apparel
  - Clothing (gloves, aprons, coveralls, etc.),
  - Eye Protection,
  - Foot Protection,
  - Head Protection.
- Limitations of Clothing and Equipment
- Decontamination of Clothing and Equipment
- Disposal of Contamination Clothing and Equipment

4. Emergency Help and Self-Rescue

- Principles of First Aid
  - Restoration of Breathing,
  - Control of Bleeding,
  - Recognition and Treatment of Physical Shock,
  - Open and Closed Wounds and Burns,
  - Fractures and Dislocations,
  - Transportation.
- Availability of Emergency Services
  - Poison Control Center,
  - Hospital and Ambulance Services,
  - Local Fire and Police Departments.

- How to Obtain Emergency Treatment in the Field
  - How and When to File a Report of Accident/Incident
- Employee Compensation Benefits

5. Sampling Techniques
   - Hazards of Sampling
   - Amount of Samples
   - Containers for Samples
   - Field Tools
     - Radioactivity,
     - Explosivity,
     - Other.
   - Sample Security
   - Packaging (DOT/EPA)
   - Shipment (DOT/EPA)

6. Safety and Health Directives
   - At the training session, the system of Safety and Healty Directives for the Love Canal Study will be explained. These Directives will be posted at the GCA Field Office and will be provided to all project team personnel. It is the responsibility of each person to read and comply with instructions given in these Directives.

The following STANDING ORDERS will be in force for the full period of the Love Canal Monitoring project:

STANDING ORDERS

- No member of the project team may enter the Love Canal area without signing in at the GCA Field Office beforehand..
  - Each person must sign, and indicate the area of his work (sector) and punch-in his reporting time on the time clock provided.
- There shall be no smoking, eating, drinking or chewing gum while in the Love Canal area.

- No open fires are permitted in the Love Canal area.
- No person may enter the fenced-in portion of the Love Canal site alone or without the knowledge of his supervisor.

TRAINING LABORATORY PERSONNEL

Each Subcontractor providing analytical services to the Love Canal Study must provide a copy of his Laboratory Safety Manual, or a description of the in-house laboratory safety program before work begins on this project. Additionally, each Subcontractor must provide to GCA/Technology Division the name of the Laboratory Safety and Health Officer and the name of an alternate. These individuals will coordinate safety and health matters relating to the laboratory aspects of this project. Lists of chemical agents which may be present in each sample category will be provided to the Subcontractor Laboratory Safety Officer as they become available.

SAMPLING, TRANSPORT AND SHIPPING PROCEDURES

Sampling

It is anticipated that samples of waste water, airborne particulate, soil, sediment and biological materials will be collected during the course of this program. No samples will be drawn from drums, barrels or other concentrated sources with the singular possible exception of possible unintentional puncturing of drums during drilling.

Safety and Health Directives will be issued for the sampling of all the above media and for the special precautions that must be taken during drilling operations. These Directives will be issued to each Subcontractor and to each individual participating in the sampling activities at the Love Canal Site. Individuals will receive these Directives during the Training Session at the Site.

Transport

All samples collected under this project are to be taken to the GCA Field Office located at Colvin Boulevard, Niagara Falls, New York and/or to the GCA Sample Bank for preparation for shipment to appropriate laboratories. No samples, specimens, or other materials may be removed from the site other than those which will be transmitted to the Sample Bank or to designated disposal areas. Samples will be transported to the Sample Bank only in approved vehicles. Personal or rental cars cannot be used for this purpose. All samples must be properly packaged following the sampling protocols specified elsewhere. In addition, all samples must be placed in a suitable container (e.g., a plastic-lined cardboard container) before transport.

Shipping

Shipping containers and labeling procedures will follow the protocol established in the QA/QC Manual. Every precaution should be taken to prevent container leakage or for sample residues to contaminate the exterior of the vessel.

## SECTION 3

## QUALITY ASSURANCE/QUALITY CONTROL

### QUALITY ASSURANCE OBJECTIVES

As mentioned in the Introduction, most of GCA's work on the Love Canal Study was, in a sense, quality assurance. The specific goals of the quality assurance program were as follows:

- Collect Representative Samples
- Maintain Chain of Custody on Samples
- Analyze Samples using Appropriate Procedures
- Achieve Comparable Results from Different Analytical Laboratories
- Estimate Precision and Accuracy Achieved
- Manage and Store Sampling and Analysis Data Generated
- Report Analytical Results in a Useable Format
- Compile a Complete Project Document Inventory

The EPA laboratories listed below had designed QA/QC programs for their areas of responsibility in the Love Canal Study.

- EMSL, Research Triangle Park
- HERL, Research Triangle Park
- EMSL, Las Vegas
- ERL, Ada
- EMSL, Cincinnati

The QA/QC measures planned by these laboratories and included in their Love Canal monitoring protocols were integrated into GCA's Quality Assurance Project Plan for the Love Canal Study. The following section briefly describes the Plan.

QA PROJECT PLAN

The Love Canal Study QA Plan was tailored to the EPA's Office of Research and Development May 1980 draft of "Guidelines and Specifications for Preparing Quality Assurance Project Plans." Content requirements stated in that document were met and the format used in the appended Model QA Plan was followed. The Love Canal Study QA plan was reviewed and approved by EPA's Project Officer and the QA officers at each of the participating EPA laboratories.

The major sections of the QA Plan are listed below:

Love Canal Study QA Plan--Major Sections

1.0 Project Description and Organization

2.0 Major Program Elements

3.0 QA Objectives

4.0 Document Control Procedures

5.0 Chain of Custody Procedures

6.0 Sampling Internal QC Checks

7.0 Analytical Internal QC Checks

8.0 Precision and Accuracy

9.0 Data Management System

10.0 System and Performance Audits

11.0 Corrective Action Procedures

Attachments: Subcontractors' QA Plan Format Suggestions

Appendix A: Sampling Procedures

Appendix B: Analytical Procedures

Appendix Q: Subcontractors' QA Plans

Appendices A, B and Q were contained in separate volumes and all four volumes were distributed in ring-binders to enable easy revision of individual sections as necessary. The separate volume format made it possible to provide detailed operating procedures including EPA's required internal QC procedures to the sampling and analysis subcontractors without giving them information on planned external QC measures such as performance audits. All four volumes were provided to EPA and GCA personnel.

## Overall Plan

The first volume provided an overview of the quality assurance measures for the entire program and was not distributed to subcontractors. The required sampling and analysis internal QC checks were presented in tabular fashion, classified according to media sampled and pollutant class measured. The replicate sampling and analysis scheme and the external QC samples used, as well as the appropriate equations to statistically estimate the precision and accuracy achieved, were documented in considerable detail in the overall plan.

Chain of Custody and Document Control procedures specific to the Love Canal Study were developed following NEIC guidelines. The QA Plan sections on these topics were reviewed by NEIC staff members and their comments incorporated. These sections were provided to each subcontractor at the start of his subcontract activity so that uniform procedures would be followed; they were also included in Appendices A and B.

## Appendix A: Sampling Procedures

This set of detailed sample collection procedures was compiled by GCA and provided to the sampling subcontractor and the supervisory geologist before any field sampling started. The manual was organized so that a specific, stand-alone procedure existed for each type of sample to be collected; the field sampler could remove and use only the procedures he needed. The appropriate type of sample container and its required cleaning, the volume or weight of sample to be collected, step by step collection procedures, field preservation and internal QC requirements, and chain of custody requirements were included in each procedure.

The complexity of the sampling program is shown by the major sections contained in Appendix A and listed below. Each section contained an overview for that media and then the individual procedures for sample collection. The procedures were dictated both by the media sampled and the analyses to be performed. It should be noted that different types of water required different sampling procedures due to equipment needs, safety considerations, preservation requirements and analytical needs.

## Appendix A--Major Sections

1.0 Air Sampling

2.0 Pollutant Transport Air Sampling

3.0 Residential Water Sampling from Sumps

4.0 Drinking Water Sampling

5.0 Sewer and Drain Water Sampling

6.0 Surface Water Sampling

7.0 Ground Water and Well Core Sampling

8.0 Soil Sampling

9.0 Sediment Sampling

10.0 Biomonitoring

11.0 Field Sample Data Forms

12.0 Document Control/Chain of Custody Procedures

Procedures for quick approval and documentation of necessary changes in the field were identified early in the program. These included identifying the necessary approvals (within the subcontractor, GCA and EPA project teams), documentation of the change request and approval in Change Logs, and incorporation of the changed procedures in revisions to Appendix A.

Appendix A was a working document, revised to meet conditions found in the field. It has been thoroughly field-tested so that the third and final revision represents a valuable resource for investigation of hazardous waste sites in general.

Appendix B: Analytical Procedures

The methodology to be used in analyzing samples collected during the Love Canal Study was provided to the analytical subcontractors in two different formats before it physically became Appendix B to the QA Plan. The analysis protocols were provided as appendices to the RFP for Sample Analysis Services in Support of the Love Canal Study so that accurate cost estimates could be made by the firms bidding on the RFP. Also, the analytical protocols specific to each subcontractor formed part of that subcontract document so that procedures to be followed, including EPA's internal QC requirements, were clearly spelled out before any samples were analyzed.

GCA prepared the analytical protocol documents, researching technical questions and, if necessary, revising the subcontract protocols. These same analytical protocols were grouped somewhat differently in Appendix B than in the subcontract documents to provide the methodology and QC requirements for the entire Love Canal Study.

The major section and subsection headings are given in Table 3.1 to indicate the content and organization of the analytical procedures manual. As with the sampling procedures manual, each analytical procedure was a complete, specific protocol that could be removed and used by the analyst. Quality Control Procedures formed a subsection of every analytical protocol and were presented in both text and tabular formats.

TABLE 3.1. APPENDIX B--SECTION HEADINGS

| | | |
|---|---|---|
| 1.0 | Air Analysis | |
| | 1.1 | Overview |
| | 1.2 | Volatile Organic Compounds on Tenax |
| | 1.3 | Pesticides and Related Compounds on Polyurethane Foam Plugs |
| | 1.4 | Metals |
| | 1.5 | Dioxins |
| 2.0 | Water Analysis | |
| | 2.1 | Overview |
| | 2.2 | Volatile Organics |
| | 2.3 | Semivolatile Organics |
| | 2.4 | Pesticides |
| | 2.5 | Metals |
| | 2.6 | Anions |
| | 2.7 | Total Organic Carbon |
| | 2.8 | Total Organic Halogens |
| | 2.9 | Dioxins |
| | 2.10 | Radioactivity |
| | 2.11 | pH |
| | 2.12 | Conductivity |
| 3.0 | Soil and Sediment Analysis | |
| | 3.1 | Overview |
| | 3.2 | Volatiles |
| | 3.3 | Semivolatiles |
| | 3.4 | Pesticides |
| | 3.5 | Metals |
| | 3.6 | Dioxins |
| | 3.7 | Radioactivity |

(continued)

TABLE 3.1 (continued)

| | | |
|---|---|---|
| 4.0 | Biota Analysis | |
| | 4.1 | Overview |
| | 4.2 | Semivolatiles and Pesticides in Animal Tissue |
| | 4.3 | Volatile Organics in Foodstuffs |
| | 4.4 | Metals in Hair |
| | 4.5 | Metals in Vegetation |
| | 4.6 | Interferon in Mouse Cells |
| 5.0 | Data Reporting Forms | |
| | 5.1 | Overview |
| 6.0 | Chain-of-Custody Procedures | |
| | 6.1 | Document Control Procedures |
| | 6.2 | Chain of Custody Procedures |
| 7.0 | Reference Material | |
| | 7.1 | Method 603 - Acrolein, Acrylonitrile |
| | 7.2 | Method 605 - Benzidines |
| | 7.3 | Method 608 - Organochlorine Pesticides and PCBs |
| | 7.4 | Method 624 - Purgeables |
| | 7.5 | Method 625 - Base/Neutrals, Acids and Pesticides |
| | 7.6 | Dioxins |
| | 7.7 | Qualitative Analysis by GC/MS |
| | 7.8 | Metals by Atomic Absorption Spectroscopy |

Appendix Q: Subcontractors' QA Plans

To establish GCA's and EPA's concern for quality early in the program, each subcontractor was required to submit to GCA a QA Plan specific to his project activity. GCA provided suggested QA Plan outlines tailored to sampling, analysis or geotechnical work to each subcontractor with his subcontract document or shortly thereafter; the detailed sections on Document Control and Chain of Custody procedures were also provided. Analytical subcontract documents included analysis protocols containing EPA's internal QC requirements.

The submitted QA Plans were reviewed with particular attention to these QC requirements; revisions were requested when necessary and the plans were conditionally approved by GCA subject to EPA's final approval. The plans were then grouped according to project activity and incorporated in their entirety in Appendix Q. This volume was distributed to EPA and the EPA Project Officer and the QA officers at the participating EPA laboratories approved the subcontractors' QA plans by their approval of the GCA QA Project Plan.

REQUIREMENTS FOR SUBCONTRACTORS' QA PLANS

Subcontractors were required to submit QA plans to demonstrate their understanding of, and capability for performing, quality work on their specific project tasks. It was not expected that different subcontractors performing the same task would submit identical QA plans but, rather, that they would meet the minimum QC requirements for that task. This would ensure that all data generated would be of at least that level of quality. It was felt that no problem would be caused by subcontractors who exceeded the minimum requirements since their data would be at or above the required level.

The measures taken to ensure the adequacy and completeness of all QA Plans, and the comparability of plans prepared for the same project activity are listed in Table 3.2. The subcontractors were grouped according to their project activity as follows:

- Sampling/Analysis Preparation
- Sample Collection
- Sample Analysis
- Geotechnical Study

Subcontractor QA plans were to be submitted to GCA within 5 days of receipt of executed subcontracts; this rapid turnaround was required by EPA and GCA in an effort to establish a firm QA/QC program prior to the start of sample collection and analysis. However, not all of the specific information requested in the QA Coordinator's suggested outlines was available during this time period. This was true primarily of the control limits and corrective actions to be used for the various analytical internal QC activities.

TABLE 3.2. SUBCONTRACTOR QA PLAN QA/QC MEASURES

- Suggested outlines specific to sampling, analysis, geotechnical project activity provided
- Internal QC requirements provided
- Document control heading format provided for QA Plans
- Overall Document Control system framework provided
  - Subcontractor described internal system operation and identified Document Control Officer
- Overall Chain of Custody system framework provided
  - Subcontractor described internal system operation and identified Sample Custodian
- Standardized Data Reporting Forms provided
  - Subcontractor described internal data review/reporting practices
- Corrective Action Requirements
  - Subcontractor described internal correction action system and identified individual(s) responsible for initiating action
- Review of submitted plans by GCA technical staff and/or QA Manager

As noted earlier, the Sampling Procedures Manual was compiled by GCA and provided to the sampling and geotechnical subcontractors before any field samples were collected. This provided a basic QA Plan for field sampling; subcontractors were to provide calibration and maintenance procedures and operational checks for their equipment, state precision and accuracy goals when possible and identify individuals responsible for various project elements.

In the case of analytical work, subcontract documents included analytical and QC procedures obtained from EPA, but a number of these protocols were missing specific control limits for surrogate compound and LCS recovery; amended protocols were distributed. Appendix B to the QA Project Plan was the final document on analytical and internal QC procedures. It contained all internal QC activities, control limits as stated by EPA and suggested corrective actions; the sections relevant to each subcontractor's task were distributed before field sample analysis commenced. Appendix B provided a basic, comparable QA Plan for analytical work with individual subcontractors providing the same types of information requested of sampling subcontractors.

GCA'S QA/QC ORGANIZATION

GCA, through its QA Coordinator and QC Coordinators for major program elements, provided liaison between EPA and the subcontractors working on the Love Canal Study. GCA served as a conduit through which information on EPA's QA/QC requirements and questions on the implementation of these requirements could flow. Each subcontractor was responsible for implementing the QA/QC requirements appropriate to his project tasks.

One of GCA's prime concerns was providing information in a uniform manner to all subcontractors engaged in the same project activity. To accomplish this, GCA assigned staff members with appropriate technical expertise to serve as QC Coordinators for the following program elements:

- Sample Collection and Handling
- Geotechnical Study
- Sample Analysis
- Data Management System

The Sampling and Geotechnical Study QC Coordinators worked principally onsite at or near Love Canal in Niagara Falls, NY; the Analytical and Data Management QC Coordinators and the QA Coordinator worked principally at GCA's Bedford, MA facility.

This section provides a brief overview of GCA's QA/QC activities in the program areas listed above and, in addition, addresses Corrective Action, Document Control and Chain-of-Custody Procedures.

SAMPLE COLLECTION AND HANDLING QA/QC

The onsite GCA Field Office and Sample Bank were significant QA measures designed to aid in the implementation of sampling QC. Their technical staff served as sampling QC Coordinators, enabling the rapid resolution of problems as they came up in the field. Table 3.3 lists the QA/QC activities of the Field Office and Sample Bank. Section 4 of this report provides more detail on these operations.

The most significant activities of the QA Coordinator related to the sampling effort were the following:

- coordinating preparation of the sampling procedures manual (Appendix A)
- establishing uniform procedures for field blanks, container cleanup and preservation of samples
- identifying the approvals needed to change a sampling procedure
- setting up a Change Log at GCA and Geomet field offices
- supervising the implementation of custody requirements
- onsite system audits

Internal QC Program

The participating EPA laboratories provided QC requirements for field blanks and replicate field samples; Geomet Technologies, Inc., the sampling subcontractor, provided operation checks for their sampling and meteorological equipment. These internal QC checks for sample collection and meteorological measurements were integrated into the QA Project Plan by GCA and presented as summary tables in Section 6 of that plan. The tables included control limits and planned corrective actions and were prepared to enable review of the sampling program internal QC measures by GCA or EPA. Section 6 is included in Appendix B to this report.

Each sampling procedure contained in the Love Canal QA Plan Appendix A included the appropriate internal QC operation check, control limits and planned corrective actions for that procedure to ensure use of these measures by field technicians. Appendix A was distributed to Geomet Technologies, Inc. who collected all samples except those related to ground water, and to JRB Associates, Inc., the supervisory geologist subcontractor, who collected ground water and well core sediment samples. Internal QC checks for Geomet's activities are summarized in Tables 6.1.1 through 6.5.1 of Section 6 in Appendix B to this report; QC checks for JRB's sample collection tasks are included in Tables 6.3.1 and 6.4.1.

TABLE 3.3. SAMPLING QA/QC MEASURES

- Standardized Sample Collection Procedures
- Each Air Collection Medium Prepared by One Laboratory from One Lot
- Onsite GCA Field Office
  - Expedited all field activities
  - Interacted with EPA and Subcontractors
  - Coordinated actual sampling operations
  - Received collected samples in the field
- Equipment Calibration Procedures/Control Limits Provided
- Onsite GCA Sample Bank
  - Directed chain of custody procedures
  - Received collected samples
  - Shipped samples to analytical laboratories
  - Inserted external QC samples in shipments
  - Maintained document control
- Documentation of Procedure/Equipment Changes
- Planned Corrective Actions
- Field Blanks and Replicate Field Samples Collected
- System Audits Onsite--Qualitative Overview
- Performance Audits--Air Sampling Flow Rates

## Onsite System Audits

These reviews of the entire sampling operation proved invaluable. The first such system audit was conducted on 20 to 22 August 1980 and included the first day of air sampling and the second day of soil sampling by Geomet Technologies, Inc. Geomet's Field Office and GCA's Field Office and Sample Bank operations were also audited.

This audit just at the start of the sampling program provided an opportunity for field personnel to raise questions and for the QA Coordinator to identify and investigate sampling procedures which might cause analytical problems. The protocol for implementing changes in the field was established during this site visit. Confusion about field blanks was found within the Geomet staff; the purpose and handling of field blanks was discussed with both Geomet and GCA personnel. Without exception, the project team members were well-motivated and a valuable interchange of information occurred.

A second site visit by GCA's QA Coordinator on 10 to 11 September 1980 included followups on previous corrective actions and an audit of JRB Associates, Inc. ground water sample collection. Special attention was given to field blank handling, sample container cleanup and field preservation requirements.

Memos on field blank handling and container cleanup were prepared and distributed during the audit. A memo on field preservation procedures was distributed the following week, after further investigation of appropriate preservation techniques by the QA Coordinator.

A third site visit on 2 to 3 October 1980 concentrated on the geotechnical study activities but included a followup audit of ground water sample collection. Earlier inefficiencies in ground water sampling had been corrected.

The reports of these audits are contained in Appendix A to GCA's QA/QC Summary Report. The reports were written in several sections so that a subcontractor received only the audit of his own activities and any overall summary; EPA and GCA personnel received all the sections.

## Performance Audits

A flow audit of the two types of air sampling pumps and the Hi-Vol samplers used in the Love Canal Study was conducted by EPA's Quality Assurance Division from EMSL/RTP. The audit included 32 of the 92 DuPont Model P125 pumps, 36 of the 64 DuPont Model P-4000 pumps and 9 Hi-Vol Samplers. It was conducted in the field, just before and just after actual sample collection on 29 September to 1 October 1980. The audit report is presented in Appendix A to GCA's QA/AC Summary Report; it shows good agreement between Geomet's and EPA's calibration values. The Mean Percent Difference between Geomet's calibration and EPA's audit calibration for all Model P125 pumps was 2.04 percent, for all Model P4000 pumps 4.46 percent and for all Hi-Vol Samplers 7.7 percent.

It is very difficult to audit water, soil and sediment sample collection when no flow or volume measurements are involved. The field blanks processed with these types of samples monitored the sample handling techniques; the samples collected in duplicate and triplicate were used to estimate overall measurement precision and audited both sampling and analytical techniques.

GEOTECHNICAL STUDY QA/QC

This part of the Love Canal Study included geophysical surveys, assessment of the site geology, installation of monitoring wells, collection of ground water samples, aquifer tests, and modeling of the groundwater flow. Four subcontractors performed this work under the direction of GCA's technical monitor.

GCA's Geotechnical QC Coordinator was onsite during all active geotechnical work. His presence was particularly valuable since standard quality measures used for sampling and analysis are not readily applicable to many aspects of geotechnical work. The QC Coordinator used the onsite GCA Field Office as his base of operations and interacted with EPA and GCA project personnel and the subcontractors to expedite the geotechnical field work.

The most significant activities of the QA Coordinator related to the geotechnical study were the inclusion of sample collection procedures specific to ground water in Appendix A to the QA Plan, and the onsite audits of ground water sample collection and general geotechnical work.

Internal QC Program

The internal QC requirements for the geophysical survey consisted mainly of equipment calibration checks provided by Technos, Inc., the subcontractor conducting the survey measurements. Table 6.6.1 in Appendix B to this report presents those QC checks. Internal QC requirements for ground water and well core sediment samples collected by JRB Associates, Inc. are summarized in Tables 6.3.1 and 6.4.1 of Appendix B.

Onsite System Audits

Collection of ground water samples was audited on 10 September 1980 and again on 3 October 1980. The 2 to 3 October site visit concentrated on the geotechnical study and included field observation of drilling crews and hydrologic testing. Geophysical survey measurements were not in progress at that time but the instrument calibration procedures were observed. Appendix A to GCA's QA/QC Summary Report contains the audit reports.

The October audit showed the four subcontractors were working cooperatively and maintaining the proposed schedule despite initial start-up problems. The drilling crews were careful and conscientious in their work; the required well drilling documentation was available and up-to-date. A supervisory geologist was onsite wherever drilling was in progress.

The supervisory geologists were conscientious in maintaining field logs, taking flow rate and conductivity measurements and interpreting the split-spoon sediment samples taken at each monitoring well. The 10 September audit of ground water samples had shown some minor problems and inefficiencies which had been overcome before the 3 October 1980 audit.

Phase 1 of the geophysical survey had been completed before the 2 October site visit and was briefly reviewed during that audit. Instrument charts and manual plots of the data were available and documented in log books; the onsite calibration techniques demonstrated were in accord with the submitted QA Plan writeups.

Performance Audits

The same techniques used for other water samples--field blanks and replicate field samples--were applied to the ground water sampling program.

SAMPLE ANALYSIS QA/QC

The samples collected at Love Canal were analyzed by 12 subcontractor laboratories and 3 EPA laboratories; analysis of replicate field samples or samples split for QA/QC purposes was conducted by 5 EPA laboratories (1 mentioned above and 4 additional laboratories). Table 3.4 lists the measures employed to ensure comparability of results between the many active laboratories.

These measures were documented in the Love Canal Study QA Plan and implemented throughout the program by all members of the project team. The subsequent validation of analytical results by EPA QA personnel showed that the planned QA/QC measures were effective in achieving comparable results from different laboratories. Internal QC analysis requirements provided analytical data for use as evaluation criteria in judging the validity of results on field samples.

The interaction of GCA with subcontractor and EPA technical staff was invaluable. The GCA analytical QC coordinators provided liaison between the subcontractor laboratories and EPA and ensured that all laboratories received the same information. If one laboratory had a technical problem or question, the appropriate EPA project staff member was consulted and, if necessary, further research was done to solve the problem. The information gained was then supplied to all laboratories to whom it would be pertinent.

GCA's principal activities related to the analytical effort included:

- coordinating preparation of the analytical procedures manual (Appendix B)
- reviewing laboratory QA Plans
- supervising external QC program

TABLE 3.4. ANALYTICAL QA/QC MEASURES

- Standardized handling and shipping procedures for all collected samples
- Standardized analysis procedures
- Internal QC Requirements specified
  - Method blanks
  - Calibration specifications
  - Calibration Checks
  - Laboratory Control Standards (LCS)
  - Internal standards
  - Surrogate compounds
  - Laboratory duplicates
- Planned Corrective Actions Outlined
- Field Blanks and Replicate Field Samples Analyzed
- System Audits Onsite--Qualitative Overview
- Performance Audits
  - Performance Evaluation Samples
  - External QC Check Samples

- interfacing with EPA and subcontractors

- onsite audits

GCA's detailed knowledge of the sample collection operation enabled the prevention of analytical problems which might have been caused by sampling procedures and the quick resolution of those which had occurred. Questions which arose in field sampling or laboratory analysis were viewed from the overall measurement perspective and addressed from that viewpoint.

Internal QC Program

Internal QC measures were specified in each analytical procedure and were made a program requirement by their inclusion in subcontract documents. These QC requirements were provided by the participating EPA laboratories and integrated by GCA into the QA Project Plan; Section 7 of that plan summarized the Analytical Internal QC Checks, including control limits and planned corrective actions, for the whole program. The section was prepared to facilitate review of the QC measures by GCA or EPA staff and is included in Appendix B to this report. Table 3.5 lists the subcontractor laboratories, their analytical tasks and the table in Section 7 which includes the appropriate Internal QC Checks for each task. It can be seen that different laboratories performing the same analyses were required to implement the same internal QC measures.

Each analytical procedure contained in the Love Canal QA Plan Appendix B included the same QC operation checks, control limits, and planned corrective actions as those listed in the summary tables. Each subcontractor received the sections of Appendix B which were relevant to his project task. However, in some cases, the control limits had not been included in subcontract documents because a data base sufficient to derive this information did not exist. GCA worked with EPA in defining control limits when required; Section 6 of this report discusses such efforts.

Control Chart Requirements

GCA included in its Requests for Proposal for analytical tasks, and in the analytical subcontract documents a section of general QA/QC requirements for the subcontractor. These requirements included the maintenance of control charts on instrument calibration and on known QC samples, such as Laboratory Control Standards (LCS). The analytical protocols for specific analyses which were included in subcontract documents and in the QA Plan Appendix B, in most cases, stated that control charts should be maintained for LCS. The laboratories were required to report their results on LCS (as well as known QC samples, surrogate compounds and internal standards) on Coding Form A2: Internal QC Report. The LCS control chart data is therefore part of the data base for the Study.

TABLE 3.5. CROSS-REFERENCE TO ANALYTICAL INTERNAL QC CHECK TABLES

| Subcontractor | Analysis task | Summary table[a] |
|---|---|---|
| Battelle Columbus Laboratories | Volatile organics on Tenax | 7.1.1 |
| PEDCo Environmental, Inc. | Volatile organics on Tenax | 7.1.1 |
| Gulf South Research Institute | Pesticides on polyurethane foam | 7.1.1 |
| | Organics in water | 7.2.1 |
| | Organics in soil and sediments | 7.3.1 |
| Southwest Research Institute | Pesticides on polyurethane foam | 7.1.1 |
| | Inorganics in water | 7.2.1 |
| | Organics and inorganics in soil and sediments | 7.3.1 |
| | Organics and inorganics in biota | 7.4.1 |
| Compuchem/Mead Technology Laboratories | Organics in water | 7.2.1 |
| | Organics in soil and sediments | 7.3.1 |
| PJB/Jacobs Engineering Group | Inorganics and organics in in water | 7.2.1 |
| | Inorganics and organics in soil and sediments | 7.3.1 |
| TRW, Inc. | Organics in water | 7.2.1 |
| Acurex Corporation | Organics in water | 7.2.1 |
| | Organics in soil and sediments | 7.3.1 |
| Energy Resources Company, Inc. (ERCO) | Inorganics in water | 7.2.1 |
| | Inorganics in soil and sediments | 7.3.1 |
| Midwest Research Institute | Organics in biota | 7.4.1 |
| Wright State University | Dioxin in all media | 7.1.1, 7.2.1, 7.3.1 |
| Advanced Environmental Systems, Inc. | TOC/TOX, pH, Conductivity in ground waters | 7.2.1 |

[a]Refers to Table in Section 7 in Appendix B of this report.

## Laboratory Site Visits/System Audits

Each laboratory was visited by GCA or EPA or both during the first month of analytical work and the working relationship established then proved valuable throughout the study. These visits constituted system audits of each laboratory's operations for the Love Canal Study; examples of the audit reports are contained in Appendix A GCA's QA/QC Summary Report. Internal QC records were inspected and chain of custody procedures were reviewed. These site visits were particularly useful in identifying and resolving sample preparation and analysis problems early in the analytical effort.

## External Quality Control Program/Performance Audits

Well-characterized samples whose true values were not known to the subcontractor laboratories were submitted to each laboratory throughout the program for use in evaluating overall performance and in estimating the accuracy achieved by each laboratory. These QC samples were shipped to the GCA Sample Bank at Niagara Falls to ensure that they were handled in the same way as field samples. However, the objective of having these QC samples indistinguishable from collected field samples was only achieved with the tenax cartridges and polyurethane foam plugs used for air sample collection. The other QC samples were easily recognizable as different from collected samples.

Two general types of QC samples were used: Performance Evaluation Samples and External QC Check Samples. The differences between the two types of samples are briefly described below and the individual samples are listed in Tables 3.6 and 3.7.

Performance Evaluation (PE) Samples--

These samples were provided by EMSL-Cincinnati and EMSL-Las Vegas as "double-blinds" (true values unknown to both GCA and the subcontractor laboratories) for use in the water, soil, sediment and biota monitoring programs. Analytical results on these samples were sent directly to the providing EPA laboratories where they were evaluated as Acceptable or Not Acceptable for each analyte reported.

EMSL-Cincinnati provided three different groups of PE samples to be shipped to appropriate laboratories at monthly intervals during the analytical work. The samples were concentrated solutions and instructions for dilution before analysis were included. GCA's QA Coordinator and Analytical QC Coordinators checked on prompt submission of results and, more importantly, investigated any Not Acceptable results. EMSL-Cincinnati sent their evaluation reports to GCA to enable this follow-up. All Not Acceptable results were checked with the individual laboratory and corrective actions initiated as necessary.

EMSL-Las Vegas supplied two groups of PE samples to be used to evaluate soil and sediment analysis procedures. The samples were NBS River sediments spiked with organic compounds as noted in Table 3.6. These samples were analogous to the "double blinds" mentioned above and were treated in a similar manner.

TABLE 3.6. PERFORMANCE EVALUATION SAMPLES USED FOR LOVE CANAL STUDY

| Sample source | Sample contents/matrix/use | Laboratories receiving samples |
|---|---|---|
| EMSL-CINN | 14 Trace Metals for AA Analysis/Aqueous Solution/Water, Soil, Sediment Samples | Energy Resources Company, Inc. (ERCO)<br>PJB/Jacobs Engineering Group, Inc. |
| EMSL-CINN | 14 Trace Metals for ICP Analysis/Aqueous Solution/Water, Soil, Sediment Samples | ERCO<br>PJB/Jacobs Engineering Group, Inc. |
| EMSL-CINN | Nitrate, Fluoride/Aqueous Solution/Water Samples | ERCO<br>PJB/Jacobs Engineering Group, Inc. |
| EMSL-CINN | Total Organic Carbon (TOC)/Aqueous Solution/ Ground Water Samples | Advanced Environmental Systems, Inc. |
| EMSL-CINN | 12 Volatile Organic Compounds/Methanol/ Water, Soil, Sediment Samples | Acurex Corporation<br>Compuchem/Mead Technology Laboratories<br>Gulf South Research Institute<br>PJB/Jacobs Engineering Group, Inc.<br>Southwest Research Institute<br>TRW, Inc. |
| EMSL-CINN | 12 Semivolatile Organic Compounds/Solution/ Water, Soil, Sediment, Biota, Samples | Acurex Corporation<br>Compuchem/Mead Technology Laboratories<br>Gulf South Research Institute<br>Midwest Research Institute<br>PJB/Jacobs Engineering Group, Inc.<br>Southwest Research Institute<br>TRW, Inc. |

(continued)

TABLE 3.6 (continued)

| Sample source | Sample contents/matrix/use | Laboratories receiving samples |
|---|---|---|
| EMSL-LV | 12 Semivolatile Compounds +5 Pesticides/ NBS River Sediment/Soil and Sediment Samples | Acurex Corporation<br>Compuchem/Mead Technology Laboratories<br>Gulf South Research Institute<br>PJB/Jacobs Engineering Group, Inc.<br>Southwest Research Institute |
| EMSL-CINN | 8 Pesticides/Acetone/Water, Soil, Sediment, Biota Samples | Acurex Corporation<br>Compuchem/Mead Technology Laboratories<br>Midwest Research Institute<br>PJB/Jacobs Engineering Group, Inc.<br>Southwest Research Institute<br>TRW, Inc. |
| EMSL-LV | 5 Pesticides/NBS River Sediment/Soil and Sediment Samples | Acurex Corporation<br>Compuchem/Mead Technology Laboratories<br>Gulf South Research Institute<br>PJB/Jacobs Engineering Group, Inc.<br>Southwest Research Institute |

## TABLE 3.7. EXTERNAL QC CHECK SAMPLES USED FOR LOVE CANAL STUDY

| Sample source | Sample contents/matrix/use | Laboratories receiving samples | Comments |
|---|---|---|---|
| EMSL-RTP | 10 Trace Metals/Hi Vol Filters/Air Samples | EMSL-RTP | 7 metals on LC[a] Monitoring List. Lab reported Sb and Be (not present); did not report Ba (present). |
| Research Triangle Institute | 6 Volatile Organics/Tenax/Air Samples | Battelle Columbus Laboratories<br>IIT Research Institute<br>PEDCO Environmental, Inc. | Sample specific to LC;[a] looked like a collected sample. |
| HERL-RTP | 6 Semivolatile Organics/Polyurethane Foam/Air Samples | Gulf South Research Institute<br>HERL-RTP<br>Southwest Research Institute | Sample specific to LC;[a] looked like a collected sample. Data handling problem at GCA. |
| EMSL-CINN | 18 Trace Metals for AA Analysis/ Aqueous Solution/Water, Soil, Sediment Samples | ERCO<br>PJB/Jacobs Engineering Group, Inc. | 13 metals on LC[a] Monitoring List. 2 concentrations below LC[a] detection limits for 7 to 8 metals. EMSL-CINN verified true values. |
| EMSL-CINN | 18 Trace Metals for ICP Analysis/ Aqueous Solution/Water Samples | ERCO | 13 metals on LC[a] Monitoring List. |
| EMSL-CINN | Nitrate, Fluoride/Aqueous Solution/ Water Samples | ERCO<br>PJB/Jacobs Engineering Group, Inc. | Labs inconsistent in reporting nitrate as N. |
| EMSL-CINN | 9 Volatile Organic Compounds/ Solution/Water, Soil, Sediment Samples | Acurex Corporation<br>Compuchem/Mead Technology Laboratories<br>Gulf South Research Institute<br>Southwest Research Institute<br>TRW, Inc. | One concentration inappropriate for LC[a] procedures. Replaced by purgeable organic compounds sample. |
| EMSL-CINN | 6 Purgeable Organic Compounds/ Solution/Water, Soil, Sediment Samples | Acurex Corporation<br>Compuchem/Mead Technology Laboratories<br>Gulf South Research Institute<br>PJB/Jacobs Engineering Group, Inc.<br>Southwest Research Institute<br>TRW, Inc. | Sample specific to LC.[a] Xylene isomers not readily separable; labs reported different isomers coeluting. |
| EMSL-CINN | Phenol/Solution/Water, Soil, Sediment Samples | Acurex Corporation<br>Compuchem/Mead Technology Laboratories<br>Gulf South research Institute<br>Southwest Research Institute | Inappropriate QC sample for LC[a] analysis procedures. True values verified by EMSL-CINN. Replaced by Semivolatile, Acid Extract Sample. SWRI instructed not to analyze. |

(continued)

TABLE 3.7 (continued)

| Sample source | Sample contents/matrix/use | Laboratories receiving samples | Comments |
|---|---|---|---|
| EMSL-CINN | 5 Semivolatile, Acid Extract Compounds/Solution/Water, Soil, Sediment Samples | Compuchem/Mead Technology Laboratories<br>Gulf South Research Institute<br>PEDCO Environmental, Inc.<br>PJB/Jacobs Engineering Group, Inc.<br>Southwest Research Institute<br>TRW, Inc. | Sample specific to LC.[a] PJB did not analyze--no similar collected samples. Compuchem did not analyze--lab handling error. |
| EMSL-CINN | 9 Semivolatile, Base/Neutral Extract Compounds/Solution/Water, Soil, Sediment Samples | Acurex Corporation<br>Compuchem/Mead Technology Laboratories<br>Gulf South Research institute<br>PJB/Jacobs Engineering Group, Inc.<br>Southwest Research Institute<br>TRW, Inc. | Sample specific to LC.[a] PJB did not analyze--no similar collected samples. |
| EMSL-CINN | 7 Chlorinated Hydrocarbon Pesticides/ Solution/Water, Soil, Sediment Samples | Acurex Corporation<br>Compuchem/Mead Technology Laboratories<br>Gulf South Research Institute<br>TRW, Inc. | Inappropriate QC Sample for LC[a] analysis procedures. Replaced by 6 Pesticides sample. |
| EMSL-CINN | 6 Pesticides/Solution/Water, Soil, Sediment Samples | Acurex Corporation<br>Compuchem/Mead Technology Laboratories<br>Gulf South Research Institute<br>PJB/Jacobs Engineering Group, Inc.<br>Southwest Research institute<br>TRW, Inc. | Sample specific to LC.[a] |
| EMSL-CINN | 1 PCB/Solution/Water, Soil, Sediment Samples | Acurex Corporation<br>Compuchem/Mead Technology Laboratories<br>Gulf South Research Institute | Aroclor 1016 sometimes reported as 1242. |
| HERL-RTP | 1 Chlorinated Dioxin/Soil/Soil, Sediment, Dust Samples | Wright State University | Sample specific to LC.[a] |
| EMSL-LV | 3 Radionuclides/Water, Sand and Clay/Water, Soil, Sediment Samples | EMSL-LV | Sample specific to LC.[a] Only 1 radionuclide reported. |

[a]LC = Love Canal Study 1-619-026

Table 3.6 lists the PE samples used in the study and identifies:

- the providing EPA laboratory (sample source)
- the analytes contained (sample contents)
- the physical state of the sample (matrix)
- the types of collected samples audited by this sample (use)
- the subcontractor laboratories receiving each PE sample (laboratories receiving samples)

External QC Check Samples--

These samples were provided by several different EPA laboratories and one subcontractor as can be seen in Table 3.7. This table follows the format of Table 3.6 and includes a Comments section. The solutions were concentrates to be diluted as directed before analysis. The true values were known by GCA but not by the subcontractor laboratories. The providing EPA laboratories referred to these samples by different names (QA samples, QC check samples, QC samples) and the term External QC Check Samples is used to encompass all of these samples and distinguish them from internal QC samples whose true values were known to the subcontractor laboratories.

EPA's QA/QC planning for the Love Canal Study had not incorporated a complete series of QC samples whose true values were known to GCA. In response to GCA's request, EMSL-Cincinnati supplied large quantities of their QC Check Samples for water quality and drinking water analyses to supplement the QC samples which had been specifically designed for the study. This provided quickly available external QC Check Samples for almost all the classes of pollutants monitored at Love Canal. Some of the water quality and drinking water QC samples initially provided had been designed for use with different analytical methods (e.g., total phenols by colorimetry) with lower detection limits than the methods used on the Love Canal Study. This problem was discovered early in the program and appropriate PE samples (Method 625 acid fraction) were substituted. Another problem was that, in general, these QC check samples were not available for shipment with the first batches of collected samples.

The External QC Check Samples were provided at the approximate rate of one QC sample for every twenty field samples of similar type shipped to an analytical laboratory. Table 3.7 lists the sample contents, their use and the receiving laboratories. Results were included in the data base to enable rapid follow-up of any questionable results.

GCA staff reviewed all External QC Check Sample Results for reasonableness and checked all questionable results with individual laboratories. Reporting and calculation errors were found in this way, but very few problems with analytical techniques were uncovered. This correlates with the internal laboratory QC results which demonstrated good analytical performance by the subcontractor laboratories.

The Comments section of Table 3.7 indicates the experience with each sample during the study. The external QC Check samples specifically designed for the study were much more useful than the general use water quality and drinking water QC Check samples. The most frequent problems with the general use samples were that they were inappropriate for the Love Canal analysis procedures and that the samples were familiar to the analytical laboratories.

EPA Quality Control Audit on GC/MS Data

In accordance with a request from the Love Canal Study Project Officer, GCA/Technology Division completed a limited study of mass spectral data from each of the laboratories performing organic analysis for the Love Canal Study. Since time and cost precluded extensive examination of all mass spectral data supplied, two analyses were selected from each laboratory for verification. Selection criteria for data to be verified was arbitrary but was influenced by several considerations, including:

- Levels of pollutants reported
- Number of compounds reported
- Toxicity of compounds reported

Using these criteria, two samples from each of the laboratories were chosen for examination. Included in this list were analyses representative of all sample types collected in the study.

The data was examined primarily to verify compound identifications. Quantitation of the substances found would have required data inputs not immediately available such as:

- Amount of sample extracted
- Concentration volume of sample
- Internal standard spike level
- Instrument response factors
- Surrogate spiking levels

While this data could be made available through interpretation of laboratory notebooks, time constraints prohibited this process.

Upon completion of this task, a summary report, Verification of Selected Mass Spectral Data From the Love Canal Study, was submitted to the Office of Research and Development, U.S. EPA, Washington, D.C. in May, 1981.

## Precision and Accuracy Estimates

The measures planned to enable the estimation of precision and accuracy included the collection and analysis of replicate samples and the analysis of well-characterized external QC check samples. Section 8.0 of the Love Canal Study QA Plan describes these measures in detail; they were used to provide estimates of:

- Intralaboratory measurement precision-based on the analysis of replicate field samples by each subcontractor laboratory.
- Intralaboratory precision for analysis only - based on the analysis of duplicate aliquots from one field sample by each subcontractor laboratory.
- Interlaboratory measurement precision - based on the analysis of replicate field samples by each subcontractor laboratory and an EPA referee laboratory.
- Accuracy for analysis only - based on the analysis of external QC check samples by each subcontractor laboratory.

All the planned measures were implemented with one exception. This involved the Tenax and foam air samples collected in duplicate sampling trains in the living areas of homes used as base sites in the residential air monitoring program. The plan was to estimate both intralaboratory and interlaboratory measurement precision from the analysis of these duplicates, using the sample splitting scheme described in Section 8.2.1 of the QA Plan. Pressures of time and difficulties of analysis prevented the complete implementation of the sample splitting scheme and only intralab measurement precision was estimated from these samples. Since two laboratories analyzed the Tenax samples and two different laboratories analyzed the foam samples, the estimation of interlaboratory precision was not as critical as when more laboratories were involved.

The computer reports described in the bullets above were prepared and submitted to EPA. Each printout included both a statistical report (mean difference, standard deviation, etc.) and an individual pairs listing which identified the samples statistically treated. The statistical report was classified by media, by pollutant and by laboratory so that it was easy to compare the performance of laboratories analyzing the same pollutant. The pairs listing was classified by lab, media and sample bank number, and pollutant.

The pairs listing gave the analytical result for each reported pollutant in each collected sample or external QC check sample and showed the wide range of reported concentrations for almost any pollutant in different collected samples. These varying concentration levels for one pollutant in one media were placed in one subgroup for statistical treatment. Defining several different concentration ranges for each pollutant and estimating precision or accuracy separately for each range would be helpful. However, so many

pollutants were reported as trace or not detected that the total number of analytical results available for statistical treatment was small. Breaking these down into different concentration ranges would result in very small statistical subgroups and, therefore, was not done.

It was recognized that if concentration levels varied widely, precision estimates would suffer from the problem described above; it was thought that estimates of accuracy based on external QC samples would not. However, most external QC samples were provided at several different concentration levels and, therefore, shared the problem.

DATA MANAGEMENT SYSTEM QA/QC

The purpose of the data management system was to collect and store all data generated as part of the Love Canal Study and to provide basic reports of the monitoring results. Table 3.8 lists the QA/QC measures employed on this program element.

Throughout the study, GCA's technical staff provided input to the Data Management staff; e.g., on design of the Sampling and Analytical Coding Manuals and Data Report forms, and were available for consultation on technical questions. The Data Management QC Coordinators' consulted with these in-house departments as necessary, and interacted with subcontractors on coding questions.

As noted in Table 3.8, the data reports were reviewed and checked at each stage in their processing by the Data Management staff and built-in computerized checks. Keypunching was machine-verified; questionable values were flagged on computer reports before they were sent to subcontractor labs for verification.

The thoroughness of the data review is demontrated in the remarkably error-free data set found in the Data Management System Audit. The audit report is included in Appendix A to GCA's QA/QC Summary Report.

CORRECTIVE ACTION SYSTEM

Section 11.0 of the Love Canal QA Plan describes the closed-loop corrective action system followed by GCA during the study. The purpose of a closed-loop system is to ensure that any quality problem is reported to a person responsible for correcting it who is part of a system ensuring action and followup on all reported problems. Both immediate and long-term corrective actions are incorporated in the system.

Each subcontractor was required to include in his QA Project Plan:

- the named individual responsible for corrective action at each stage of his operations.

- Internal QC procedures which met or exceeded EPA's internal QC requirements and included control limits and corrective actions to be taken if these limits were exceeded.

## TABLE 3.8. DATA MANAGEMENT QA/QC MEASURES

- Uniform Coding Standards
  - Individual coding manuals for sampling data and for analysis data
  - Individual coding forms for sampling data reporting and for analysis data reporting
- Log-in of all data forms sent to or from GCA/Technology Division
  - Forms traceable by serial number and/or sample ID number
- Review of Data
  - Check of coding forms by GCA for reasonableness before keypunch
  - Check of computer reports by GCA for reasonableness before sending to subcontractor lab for verification
  - Check of computer reports by each subcontractor lab to verify entries
  - Alert reports of concentrations exceeding alert levels
- Computer Card Preparation
  - Acceptable ranges of values supplied to keypunch operators
  - Key-verification of all cards
- Computer Check and Edit of Data
  - Edit check programs specific to sampling data, analysis data and verification action data
  - ID Cross-reference file to prevent double entries
  - Coordinates file - automated entry of sampling site coordinates
- Computer Program Safeguards
  - All programs tested with legal and illegal test data before actual data was processed.
  - "Levels" assigned to data files during program execution to prevent access by out of sequence programs
- Documentation of Changes to Data
  - Notations on coding forms by GCA staff
  - Notations on computer reports by GCA staff
  - Notations on computer reports by subcontractor labs
  - Notations in project workbooks by GCA staff
  - Verification action reports by GCA DMS staff

Subcontractors were free to follow their own corrective action system as long as the stated requirements were met. Each subcontractor's project document inventory contains the documentation of corrective actions taken by that subcontractor. GCA did not monitor this documentation.

Summary tables of the EPA internal QC requirements are contained in Sections 6 and 7 of the Love Canal Study QA Plan. Each media sampled or analyzed is covered in a separate table and control limits and planned corrective actions are included. To ensure actual use by field and laboratory technicians, the Appendix A Sampling Procedures and Appendix B Analytical Procedures included the appropriate internal QC requirements.

Immediate Corrective Action

The control limits and planned corrective actions were provided to enable the uniform application of appropriate corrective actions as part of normal operating procedures. The actions taken were to be noted in field or laboratory notebooks but no other formal documentation was required. These on-the-spot corrective actions were an everyday part of the QA/QC system; they helped to avoid the collection of poor quality data.

Long-Term Corrective Action

GCA placed any problem not solved by immediate corrective action into the long-term category requiring appropriate documentation and followup. The initial record of the need for corrective action, the problem investigation, and the actions taken was made in the project workbook maintained by each GCA technical staff member.

GCA's routine policy is to initiate a Corrective Action (CA) Request Form for each long-term corrective action. The time pressures of the Love Canal Study caused these forms to be initiated after the fact in many cases, and not at all in some cases. However, workbook documentation was dated and complete and provided the action dates given on the CA Forms which were prepared by GCA. These forms are contained in Appendix C to GCA's QA/QC Summary Report; memos or letters which formed part of the corrective action are included to enable tracing the action.

DOCUMENT CONTROL/CHAIN-OF-CUSTODY PROCEDURES

The procedures used on the Love Canal Study were defined by the GCA QA Coordinator working with NEIC staff members, and following guidelines developed from:

- NEIC Policies and Procedures Manual, EPA-330/9-78-001R, Section II.
- Enforcement Considerations for Evaluations of Uncontrolled Hazardous Waste Disposal Sites by Contractors, NEIC, April 1980, Sections VIII and IX.

NEIC staff members reviewed the project-specific procedures and their comments were incorporated. GCA's QC Coordinators and QA Coordinator consulted with NEIC on any questions throughout the program.

A detailed writeup covering both document control and chain-of-custody procedures and requirements was provided to each subcontractor with his subcontract documents, or shortly thereafter. In addition, Appendix A to the QA Plan contains these procedures with special emphasis given to the sampling aspects; Appendix B contains a Document Control/Chain-of-Custody Section directed to the needs of analytical laboratories. Sections 4 and 5 in the overall QA Plan volume present the same information, addressing both the sampling and analysis requirements.

Document Control Procedures/Document Inventory

The purpose of document control is to ensure that all project documents will be accounted for and assembled into a document inventory when a project is completed; this facilitates tracing the history of the entire project or any part of it. The system implemented by GCA during the Love Canal Study was managed by Document Control Officers (DCOs) who were responsible for issuing, controlling and maintaining records of controlled documents.

GCA identified the principal items subject to document control, provided a project numbering system including individual subcontractor codes and provided serialized sample identification and custody forms. GCA's DCO at the onsite Sample Bank maintained overall document control on all items related to sample collection and shipment. GCA's DCO at Bedford logged in all project documents, including data reporting forms, received at Bedford.

At the conclusion of project activity, each subcontractor was required to submit his complete project document inventory, classified according to the guidelines provided, to GCA for subsequent transferral to EPA. GCA has assembled these subcontractor document inventories at its Bedford headquarters; they will be submitted to EPA on request or at the conclusion of GCA's project activity.

Use of Project Notebooks--

GCA required that its own and subcontractor technical staff members maintain complete and traceable records of all project activity--in bound laboratory notebooks, when appropriate. The onsite Sample Bank DCO issued bound notebooks and Field Data Sheets to the Sampling and Geotechnical subcontractors; Subcontractor and GCA/Bedford DCOs maintained control of notebooks issued to their staff. These notebooks form an important part of the project document inventory.

Chain-of-Custody Procedures

The purpose of chain-of-custody procedures is to document the identity of the sample, and its handling, from its first existence as a sample until information derived from it is introduced as evidence during an enforcement proceeding. Customized sample identification tags and custody records were

provided by GCA to subcontractors and GCA's onsite Sample Bank directed chain-of-custody procedures and transferred custody of collected samples and QC samples to analytical laboratories. Each appropriate subcontractor was required to identify a Sample Custodian and to maintain document control of custody records.

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## SECTION 4

## SAMPLING

Once standardized sampling protocols had been established as discussed in the previous section, the next major responsibility for the sampling element of the GCA program was to select a qualified subcontractor.

The various sampling protocols were combined into one consistent Bid Package. The number of samples to be collected using each protocol was stipulated as well as the schedule so that comparable bids would be received.

The bid package also included Special Instructions, Technical Evaluation Criteria, General Instructions, Representations, Certifications and Acknowledgments, Certificate of Current Pricing Data and Delivery Requirements. Of particular relevance here is the list of Technical Evaluation Criteria that was contained in the RFP and is listed in Table 4.1.

The various EPA laboratories had supplied GCA with the names of firms that were thought to have the capability of undertaking the sampling task. Since time did not permit the formal announcement of the solicitation, the list of 10 firms supplied by EPA was used as the prospective bidder's list. Each of the firms was contacted by telephone on 14 July 1980 to be invited to the 17 July Bidder's Conference in Buffalo, New York. Confirmations of these invitations were issued by TELEX on 16 July 1980.

The firms invited to the bidder's conference included the following:

1. Battelle Memorial Institute
   505 Kings Avenue
   Columbus, OH 43201

2. Research Triangle Institute (RTI)
   Post Office Box 12194
   Research Triangle Park, NC 27709

3. Radian Corporation
   Post Office Box 9948
   Austin, TX 78766

4. PEDCo Environmental, Inc.
   11499 Chester Road
   Cincinnati, OH 45246

TABLE 4.1. TECHNICAL EVALUATION CRITERIA
(GCA 1-619-026-222-001)

Technical proposals received in response to the subject RFP will be evaluated using the following equally weighted criteria:

I. Offeror's immediate availability to initiate sampling, ability to respond on short notice with sufficient field personnel, and ability to complete the sample collection program by 31 October 1980.

II. Offeror's understanding of the scope and magnitude of the sampling effort required as demonstrated in the proposed technical approach.

III. Offeror's experience in sampling environmental pollutants in air, water, soils, sediment and biota.

IV. Offeror's proposed overall program management including qualifications of assigned personnel; i.e., experience, capability, and percentage of effort devoted to the program.

V. Offeror's experience in sampling organic pollutants by means of sorbent media.

VI. Offeror's ability to supply the required sampling equipment and spare parts.

VII. Offeror's Quality Assurance/Quality Control Plan.

5. IIT Research Institute
   10 West 35th Street
   Chicago, IL 60616

6. Geomet
   15 Firstfield Road
   Gaithersburg, MD 20760

7. Southwest Research Institute
   Post Office Box 28510
   San Antonio, TX 78284

8. Midwest Research Institute
   452 Volker Blvd.
   Kansas City, MO 64110

9. Gulf South Research Institute
   Post Office Box 1177
   New Iberia, LA 70560

10. Environmental Science & Engineering
    Post Office Box ESE
    Gainesville, FL 32604

Of the 10 organizations invited to the bidder's conference, eight were actually in attendance. The eight include the following:

1. Battelle Columbus Laboratories

2. IIT Research Institute

3. Gulf South Research Institute

4. Geomet

5. Southwest Research Institute

6. Radian Corporation

7. PEDCo Environmental, Inc.

8. Environmental Science & Engineering

At the bidder's conference the RFP package was distributed to all in attendance. All aspects of the cost and technical requirements were discussed in detail by GCA personnel with questions from the attendees encouraged as each aspect of the program was discussed. Any remaining questions that had not been dealt with during the previous discussions were answered so that each of the prospective bidders had an equal understanding of the program requirements. The due date for proposals was 21 July 1980 at 5:00 p.m. EDT.

The entire bidder's conference was transcribed by a Notary Public and typed copies of the proceedings were available to GCA at the end of the day for documentation.

Five firms responded with proposals in response to the RFP. These included:

1. Battelle Columbus Laboratories

2. IIT Research Institute

3. Geomet

4. PEDCo Environmental, Inc.

5. Environmental Science & Engineering

Based on the technical evaluation of these five proposals, two firms were invited to GCA for best and final discussions. This process led to the selection of Geomet Technologies, Inc. as the sampling subcontractor.

With this task completed, efforts were immediately directed to getting the sampling effort underway.

GCA established a centrally-located field office on Colvin Boulevard, just north of the Love Canal. This location facilitated communications, sampling operations monitoring, chain-of-custody protocol, and subcontractor coordination during the sampling campaign.

The primary responsibility of the field technical staff was Quality Assurance and Quality Control of field sampling procedures. Field sampling crews were observed to assure that proper protocols were followed for:

- sample container preparation
- sampling equipment calibration
- sample site documentation
- sample handling
- sample preservation
- sample labeling
- sample chain-of-custody form preparation

Sampling of sumps, soil, air, and water was monitored on a daily basis; initially, to ensure that procedures were followed and uncertainties could be quickly resolved. Once the sampling crews became proficient, monitoring was

accomplished by periodic spot checks to assure that protocols were being followed throughout the program. A protocol log book was kept by the field office personnel to document any changes in protocols and QA/QC problems.

The following sampling protocol components were monitored at each sampling site visit:

- sample container preparation
  - correct volume
  - correct cleaning procedure
  - correct cap which was similarly cleaned
  - proper storage of containers
- sample collection and handling
  - clean sampling equipment
  - cleaning of equipment between samples
  - use of only glass, teflon or stainless steel for sample contact
  - care to avoid contamination of samples
  - liquid portions of samples collected before sediments to avoid mixing
  - Texax and PUF samples handled with nylon gloves
  - protocol followed for all samples.
- sample preservation
  - correct preservative for type of analysis
  - correct normality of preservative
  - expiration date not exceeded
  - correct amount of preservative used
  - sample kept well iced and doublebagged
  - samples delivered to sample bank truck every 4 hours

- chain-of-custody
  - sample tags completely prepared
  - sample container numbers matched the correct chain-of-custody form
  - samples doublebagged with tag inside
  - chain-of-custody forms and tags properly completed and signed
  - recheck all information upon entry into sample log book

Protocol changes were made during the testing period. The field office personnel were responsible for notifying all affected field crew and monitoring and documenting the implementation of the changes.

Another important function of the GCA field office personnel was security and sample integrity. Twelve-hour continuous air samples were collected at over 60 unoccupied homes. Security against tampering and vandalism was essential to ensure the integrity of these samples. The following security measures were implemented for the protection of the samples.

- all homes were locked and secured.
- additional padlocks and hasps were installed on all entrances, with master keys issued only to the subcontractor and the GCA field office.
- each home was equipped with a log book in which any one who entered the building was required to sign in indicating name, date, time, and reason for being there, and any additional comments or observations upon entering the home.
- evidence tape was placed on all windows and doorways serving as an indicator for any unauthorized entry of the homes.
- upon entry all personnel were to check the evidence tape for breaks to verify unauthorized entry. Observations were to be recorded in the log book at the home.
- a private security guard was hired to make hourly inspections of the homes during the night and report any infractions upon the homes immediately to the field office personnel.

The homeowners were escorted by field office personnel if they requested entry. The homes were kept up to the condition in which they were accepted for the program, requiring repairs of damage by vandalism, break-ins and accidents. A written appraisal of all privately-owned homes was done by a licensed appraiser prior to the sampling program to provide proper protection and liability of all parties involved.

At those locations where outside air samples were being taken, totally enclosed cages were built to accommodate the hi-vol, PUF and Tenax samplers. These cages were inspected for tampering by GCA personnel during the day, and by the security guard at night. All wells which were sampled were equipped with locking caps to which only the samplers had a master key. This was to protect against tampering or unauthorized use of the wells.

The subcontractors were required to collect and deliver all air samples to the sample bank truck located at the GCA field office within 4 hours of sampling completion. All other samples; i.e., soil, water, and biota were taken and delivered to the sample bank by the samplers directly.

The field office was further responsible for carrying out or delegating the following tasks:

- hazardous waste disposal
- health and safety monitoring and enforcement
- payment of utilities
- public relations

A hazardous waste disposal contractor was engaged to handle the wastes and paper work associated with them. The waste was turned over the contractor doublebagged, coded, labeled with the proper chain-of-custody forms and tags, and sealed in Department of Transportation (DOT) approved barrels to conform with shipping regulations. The barrels were kept under lock and key until custody was transferred to the hazardous waste contractor.

Field office personnel monitored the adherence of all field crew members to health and safety protocol as listed below:

- sampling personnel must wear rubber suits, boots and fit-tested halfmasks, or completely contained breathing apparatus as needed in hazardous areas.
- all sewers and sumps must be checked with photoionization hydrocarbon monitor to assure the safety of entering such areas.
- all samples must be handled with the proper care and respect for their constituents.
- traffic control must be provided when sampling in roadways.

Payments of utility bills for the homes were made through the GCA field office. Reimbursements were also made for accommodations and meals to those homeowners who participated in the occupied/unoccupied field studies.

The field office also provided a public relations center when directed by the EPA on-scene coordinator. Information and site visits were provided as well as the briefing of officials on the program background and status. The field office also served as a communications point for homeowners and samplers to coordinate sampling times which would be convenient for the residents of occupied homes.

Air, sump, surfacewater, sewer, soil and biota sampling sites were selected by EPA on location. Homeowners in the Love Canal area were asked to volunteer their homes for sampling. Those homeowners in residence near the Love Canal who voluntered their homes were relocated for the duration of the sampling campaign. The Love Canal area was divided into 11 regions or sampling areas. Sixty-four (64) homes within these sampling areas were selected for the study. Sites were chosen on the basis that the owner would allow sampling to be done in his home, electrical services were available, running water was available, and the house had a sump. One site in each area which met all of these criteria was designated as base site for that sampling area. High-vol air samplers were installed outside these homes. The remaining homes in each area (fixed sites) were sampled at the discharge points which were available. Sites were also selected for background air levels and air tranport. Special occupied/unoccupied air samples were also taken during the sampling program. Selected homes were sampled occupied from October 16 through October 20, and unoccupied (following 2 days to ventilate the homes from October 23 to October 27. All sites were coded by the GCA field office, plotted on a USGS map and coordinates were established for each sampling point. Table 4.2 is a summary of the types of sampling sites indicating the numbers of samples collected for each medium, including duplicates, spikes and blanks. Table 4.3 is a daily summary for all field samples indicating the number of samples collected each day by medium excluding duplicates, spikes and blanks.

The GCA field office was responsible for the master log of all samples. As samples were received from field personnel they were logged-in in accordance with the attached chain-of-custody forms. All available information, including the sampling point map coordinates were recorded prior to relinquishing the samples to the sample bank truck which was taken to the sample bank every evening.

Exceptions to this chain-of-custody procedure were followed for: air samples, which after being logged-in at the field office were transported in iced coolers directly to the sample bank; the night sump samples associated with the air sampling, which were taken directly to the sample bank; and biota samples which were also delivered directly to the sample bank.

TABLE 4.2. SUMMARY OF LOVE CANAL SAMPLING ACTIVITIES

| Medium | Sites | Samples |
|---|---|---|
| **Air** | | |
| Regular Program | 66 | |
| Occupied/Unoccupied | 6 | |
| Transport Study | 5 | |
| Request | 2 | |
| | 79 | 3,092 |
| **Water** | | |
| Domestic Tap | 47 | |
| Sumps | 50 | |
| Surface Water | 18 | |
| Sewers | 30 | |
| | 145 | 3,260 |
| **Sediment** | | |
| Surface Water | 18 | |
| Sewers | 30 | |
| | 48 | 338 |
| **Soil** | | |
| Regular Program | 168 | |
| Request | 5 | |
| | 174 | 1,503 |
| **Biota** | | |
| Crayfish | 2 | |
| Worms | 9 | |
| Mice Traplines | 12 | |
| Dogs | 40 | |
| Silver Maple | 31 | |
| Potato/Oatmeal | 19 | |
| | 113 | 465 |
| Program Total | 559 | 8,658 |

TABLE 4.3 SUMMARY OF DAILY SAMPLING ACTIVITY [a]

| Sample collection Date | Air | Water | Soil | Sediment | Biota | Sample date total |
|---|---|---|---|---|---|---|
| July 1980 | | | | | | |
| 7 - 30 | | 4 | | 2 | | 6 |
| August 1980 | | | | | | |
| 8 - 8 | | 7 | | 31 | | 38 |
| 9 | | 10 | | 18 | | 28 |
| 10 | | 9 | | 30 | | 39 |
| 11 | | 12 | | 38 | | 50 |
| 12 | | 8 | | 14 | | 22 |
| 19 | | | 17 | | | 17 |
| 20 | | | 23 | | | 23 |
| 21 | | | 19 | | | 19 |
| 22 | 15 | 32 | 71 | | | 118 |
| 23 | | 24 | 91 | | | 115 |
| 26 | | 39 | 17 | 31 | | 87 |
| 27 | | 15 | 30 | 23 | | 68 |
| 28 | | | 33 | | | 33 |
| 29 | | | 10 | | | 10 |
| 30 | 64 | 41 | | | | 105 |
| September 1980 | | | | | | |
| 9 - 3 | | 101 | | | | 101 |
| 5 | | 18 | | | | 18 |
| 6 | | 2 | | | | 2 |
| 8 | 95 | 14 | | | | 109 |
| 9 | | 80 | | | | 80 |
| 10 | | 11 | | | | 11 |
| 12 | | 11 | | | | 11 |
| 15 | | 35 | | | | 35 |
| 16 | 146 | 86 | | | | 232 |
| 17 | | 30 | | | | 30 |
| 18 | | 42 | | | | 42 |
| 19 | | 5 | | | | 5 |
| 20 | 4 | | | | | 4 |
| 21 | 151 | 72 | | | | 223 |
| 22 | | 66 | 25 | 28 | | 119 |
| 23 | | 74 | 36 | 20 | | 130 |
| 24 | | 63 | 32 | 15 | | 110 |
| 25 | | 4 | 28 | | 10 | 42 |
| 26 | 141 | 148 | 34 | | | 323 |
| 27 | | 20 | 42 | | 5 | 67 |
| 28 | | 6 | | 5 | 6 | 17 |
| 29 | 83 | 20 | | | 7 | 110 |
| 30 | 167 | 121 | 34 | | | 322 |
| October 1980 | | | | | | |
| 10 - 1 | | 160 | 72 | 4 | | 236 |
| 2 | | 56 | 38 | 1 | 27 | 122 |
| 3 | | 81 | 55 | | 4 | 140 |
| 4 | 61 | | | | 12 | 73 |
| 5 | 164 | 79 | | | 1 | 244 |
| 6 | | 24 | 68 | | 4 | 96 |
| 7 | | | 62 | | 1 | 63 |
| 8 | | 69 | 83 | | 13 | 16[c] |

(continued)

TABLE 4.3 (continued)

| Sample collection Date | Air | Water | Soil | Sediment | Biota | Sample date total |
|---|---|---|---|---|---|---|
| October 1980 | | | | | | |
| 10 - 9 | 161 | 90 | 80 | | 17 | 348 |
| 10 | | 64 | 71 | 27 | 7 | 169 |
| 11 | 5 | 41 | 42 | 10 | 1 | 99 |
| 12 | 2 | 35 | | | | 37 |
| 13 | | | 59 | | 9 | 68 |
| 14 | 71 | 115 | 67 | | 19 | 272 |
| 15 | 151 | 154 | 71 | | 18 | 394 |
| 16 | 17 | 54 | 34 | | 18 | 123 |
| 17 | 6 | 42 | 10 | | | 58 |
| 18 | 6 | 67 | | | 13 | 86 |
| 19 | 7 | 28 | | | | 35 |
| 20 | 160 | 32 | 29 | | 16 | 237 |
| 21 | 11 | 14 | 41 | | 5 | 71 |
| 22 | 6 | | 39 | | 12 | 57 |
| 23 | 6 | | 45 | | 42 | 93 |
| 24 | 6 | | 41 | | | 47 |
| 25 | 158 | | | | | 158 |
| 26 | 13 | | | | | 13 |
| 27 | 6 | | | | 3 | 9 |
| 28 | 19 | 43 | | 5 | 30 | 97 |
| 29 | 1 | | | | 23 | 24 |
| 30 | 95 | 7 | | | 41 | 143 |
| 31 | 11 | | | | | 11 |
| November 1980 | | | | | | |
| 11 - 1 | 1 | | | | 1 | 2 |
| 23 | | 6 | | | | 6 |
| December 1980 | | | | | | |
| 12 - 16 | | 1 | | | | 1 |
| 17 | | 2 | | | | 2 |
| 18 | | 14 | | | | 14 |
| Total | 2,010 | 2,508 | 1,549 | 298 | 369 | 6,734 |

[a]Blanks and QA/QC samples are not included.

## SECTION 5

## GEOTECHNICAL

### GENERAL

As part of the overall Love Canal investigation, four major geotechnical operations were undertaken:

- Supervisory Geologist Activities
- Monitoring Well Installation
- Geophysical Surveys
- Ground Water Modeling

These individual operations were required for the complete hydrogeologic interpretation of the Love Canal area and the possible effects on ground water quality by the migration of contaminants from the burial site.

Five independent subcontractors were eventually selected by GCA to perform the geotechnical task. GCA in its role as the prime contractor was responsible for the coordination of all the operations with the overall program.

### SCOPE OF WORK

#### GCA Protocols and Evaluation Criteria

In conjunction with the U.S. EPA R.S. Kerr Research Laboratory in Ada, Oklahoma, the scope of work was defined by GCA. The geotechnical task was subsequently divided into four separate operations for bidding purposes. Two separate requests for proposals (RFP) were prepared for bidders. The first RFP included the supervisory, geophysical, and ground water modeling operations while the second was exclusively well drilling. Both RFPs contained detailed protocols specified by GCA in accordance with the requirements of the scope of work. Proposals were evaluated on specific criteria (Tables 5.1 and 5.2).

TABLE 5.1. TECHNICAL EVALUATION CRITERIA: DRILLING PROGRAM

Responses to the subject RFP were evaluated using the following equally weighted criteria:

I. Offeror's immediate availability to initiate drilling with sufficient drill rigs and ability to complete the drilling program by 15 October 1980. The number of available drill rigs and crews will be one measure of these abilities.

II. Offeror's Quality Assurance/Quality Control Plan.

III. Offeror's experience in drilling the required types of wells in similar formations and installing the required well points with appropriate grouting to prevent interaquifer contamination.

IV. Offeror's specific experience in the greater Niagara Falls area.

V. Offeror's proposed overall program management approach including qualifications of assigned personnel; i.e.; experience, capability, and percentage of effort devoted to this program.

VI. Offeror's Health and Safety Plan.

TABLE 5.2. TECHNICAL EVALUATION CRITERIA: SUPERVISORY GEOLOGIST ACTIVITIES, GEOPHYSICAL SURVEYS, AND GROUND WATER MODELING

Responses to the subject RFP were evaluated using the following equally rated criteria:

I. Offeror's immediate availability to initiate work on the project. Availability of required equipment.

II. Offeror's Quality Assurance/Quality Control Plan.

III. Offeror's experience in performing the required types of work.

IV. Offeror's proposed overall program management including qualifications of assigned personnel; i.e., experience, capability, and percentage of effort devoted to this program.

V. Offeror's Health and Safety Plan.

VI. Offeror's specific experience in the greater Niagara Falls area.

The protocols which were established by GCA included ground water and sediment sampling, rock coring, well drilling, a Quality Assurance/Quality Control plan, and a safety plan. Each bidder was required to submit individual QA/QC and safety plans in conformance with GCA. The ground water and sediment sampling protocols are contained in GCA's Quality Assurance Plan, Love Canal Study, Appendix A: Sampling Procedures. These protocols included procedures for purging wells, sample preservation, documentation, and chain-of-custody practices. The well drilling procedures were outlined in the second RFP and are summarized here.

GCA reviewed available drilling techniques for monitoring well installation with several experts and selected those techniques which provided the maximum effectiveness in the sediment and rock types found in Niagara Falls. Prevention of cross-contamination was also paramount in the selection of drilling techniques.

Hollow-stem augering was the method chosen for drilling through the unconsolidated sediments. Drilling to depths below which auger refusal occurred was accomplished by utilizing two types of water-rotary drill bits: NX diamond coring bits, and tri-cone roller rock bits.

The monitoring wells were constructed using 2 in. and 4 in. steel casing with threaded flush-joint couplings. Well-screens were the 5 ft long wire-wound stainless steel type welded to the casing.

Two basic types of monitoring wells were designed: shallow (A-type) wells completed in the upper portion of the glacial till, and deeper (B-type) wells into the dolomitic bedrock. These two types of wells were generally paired together approximately 10 ft apart. Several of the bedrock wells were later drilled to a greater depth in order to penetrate the entire Lockport Dolomite and extend to the Rochester Shale. Also, seven 2 in. PVC casings were temporarily installed in the overlying clay unit for the purpose of performing slug tests at various depths.

Bid Preparation and Briefing

The bidding structure was designed to allow contractors to bid on one or more of the geotechnical operations; the exception being that the well drilling operation could not be performed in conjunction with any other geotechnical operation by the same contractor.

Written communications were mailed to a list of qualified contractors recommended by EPA and GCA (Table 5.3). Invitations were also extended to contractors requesting to be included on the mailing list.

A bidders conference was held on 28 July 1980 at the Airways Motor Inn located in Buffalo, New York. The conference was followed by a site visit to the Love Canal area. Attendance at the meeting was mandatory to receive an RFP and offer a bid. Proposals were due at GCA offices in Bedford, Massachusetts by 5 p.m. on 1 August 1980.

TABLE 5.3. PROSPECTIVE BIDDER'S LIST GEOHYDROLOGY SUBCONTRACTS LOVE CANAL STUDY

| | | |
|---|---|---|
| 1. | Battelle NW<br>P.O. Box 999<br>Richland, WA 99352<br>Attn: Stuart Brown<br>509-375-3607 | A |
| 2. | Empire Soils<br>S. 3858 Sheldon Road<br>Orchard Park, NY<br>Attn: Dean Anderson<br>716-662-5525 | C |
| 3. | Engineering Enterprises, Inc.<br>1225 West Main, Suite 215<br>Norman, OK 73069<br>Attn: John Fryberger<br>405-329-8300 | C |
| 4. | Geotechnical Engineers, Inc.<br>1017 Main St.<br>Winchester, MA<br>Attn: Bartlett Paulding<br>617-729-1625 | AB |
| 5. | GeoTrans<br>P.O. Box 2550<br>Reston, VA 22090<br>Attn: James Mercer<br>702-435-4400 | A |
| 6. | Goldberg-Zoino, Assoc.<br>30 Tower Road<br>Newton, MA<br>Attn: John Ayres<br>617-969-0050 | A |
| 7. | Haley and Aldrich<br>238 Main Street<br>Cambridge, MA 02142<br>Attn: Richard Stulgis<br>617-492-6460 | A |

(continued)

TABLE 5.3 (continued)

| | | |
|---|---|---|
| 8. | International Resource Consultants<br>P.O. Box 1306<br>Camp Verde, AZ 86322<br>Attn: Richard Tinlin<br>602-567-3139 | A |
| 9. | JRB Associates, Inc.<br>8400 Westpark Drive<br>McLean, VA 22102<br>Attn: Robert Colonna | A |
| 10. | Law Engineering<br>2749 Delk Road<br>Marietta, GA 30067<br>Attn: Don Miller<br>404-952-9005 | ABC |
| 11. | Radian Corporation<br>P.O. Box 9948<br>Austin, TX 78766<br>Attn: Kirk Holland<br>512-424-4797 | A |
| 12. | Rochester Drilling Co.<br>45th Street<br>Rochester, NY<br>Attn: Carl Asprinio<br>716-458-0821 | C |
| 13. | Steffen Wolff<br>Fisher Road<br>E. Syracuse, NY<br>Attn: Steffen Wolff<br>315-437-1429 | C |
| 14. | Stephen A. Alsup and Assoc., Inc.<br>2344 Commonwealth Avenue, Suite 1-2<br>Newton, MA 02166<br>Attn: Stephen A. Alsup<br>617-965-0397 | B |
| 15. | Technos, Inc.<br>P.O. Box 330891<br>Miami, FL<br>Attn: Richard C. Benson<br>305-858-4665 | AB |

(continued)

TABLE 5.3 (continued)

| | | |
|---|---|---|
| 16. | Western Geophysical<br>P.O. Box 550<br>Westboro, MA<br>Attn: Vincent Murphy<br>John Doherty<br>617-366-9191 | AB |

Key:

A = Geohydrology studies including modeling
B = Geophysical survey
C = Drilling

## Selection of Subcontractors

A total of 13 proposals were received for the 4 geotechnical operations. Proposals for each operation were ranked procedurally and technically by GCA personnel. Unacceptable or technically deficient proposals were eliminated and acceptable proposals were then evaluated jointly by EPA and GCA personnel. A consensus was reached on subcontractor selection and subcontracts were negotiated.

Two proposals were received in response to the drilling services RFP: Empire Soils, Inc. and Rochester Drilling. Only the Empire Soils proposal was responsive to all of the requirements of the RFP. Discussions with Empire Soils indicated that the proposer was technically qualified to perform the work and could field the required number of rigs and crews to accomplish the work according to EPA's schedule. A subcontract was neogtiated with Empire Soils.

In response to the supervisory geologist services RFP, two proposals were received before the submission deadline: Engineering Enterprises, Inc., and JRB, Inc. After initial review at GCA, the JRB and Engineering Enterprises proposals were reviewed and discussed by Jerry Thornhill (EPA, Ada), Paul Beam (EPA, Washington), and David Cogley (GCA) at a 8 August 1980 meeting in Research Triangle Park, NC. Both firms were judged to be well qualified. JRB was selected on the basis that they were more familiar with the Niagara Falls geology and the principal investigator for JRB was proposed to be assigned to the project full-time. A subcontract was negotiated with JRB.

Four proposals were received in response to the geophysical survey RFP: Steven Alsup, International Resource Consultants (IRC), Technos and Weston Geophysical. Proposals were scored numerically on: quality assurance, health and safety, management, methods preposed, availability, and general experience. This scoring showed that IRC offered services only for complex resistivity surveys and magnetometry whereas the other three firms offered services for: ground penetrating radary, simple sensitivity, electromagnetic induction conductivity, metal detection and magnetometry. Of these latter three firms, Technos was judged to be the most experienced in applying these methods to hazardous waste site investigations. At the meeting on 8 August, EPA and GCA personnel first determined that complex resistivity alone or in combination with magnetometry could not offer guidance to other program elements. In addition, there was no experience with the use of complex resistivity at hazardous waste sites. For these reasons, the IRC proposal was eliminated from further consideration. After further consideration of the remaining three proposals, Technos was selected on the basis of their experience, technical approach, interpretive capability and equipment. A subcontract was negotiated with Technos.

In response to the modeling RFP, two proposals were received before the submission deadline: Battelle and Geotrans. The Battelle and Geotrans proposals were both judged to be technically acceptable. Battelle proposed to assign to the project one or more persons with extensive experience at Love Canal. At the 8 August review meeting, Geotrans was selected on the basis of price. A subcontract was negotiated with Geotrans.

## SUBCONTRACTOR OPERATIONS

### Supervisory Geologist

The role of the Supervisory Geologist was to provide trained personnel familiar with well drilling techniques to monitor the activities of the drillers. Each supervisor was responsible for core and well logging descriptions. They were also responsible for recording all hydrological data, conducting aquifer tests, and distributing the data to the other geotechnical contractors.

JRB Associates of Maclean, Virginia was selected as the Supervisor Geologist contractor. JRB supplied a multidisciplinary field team and senior management personnel for the project. JRB also provided a special team to purge the wells and sample the ground water.

### Geophysical Surveys

Technos Inc. of Miami, Florida was the geophysical contractor for this project.

These surveys were performed in two phases: a preliminary methods testing and base-line establishment phase and a confirmatory phase. The preliminary phase utilized the following exploration methods:

- Ground Penetrating Radar
- Resistivity (Surface)
- Electro-Magnetic Induction (Shallow and Deep)
- Seismic Reflection and Refraction
- Magnetometry/Metal Detection

The surveys were conducted in areas of suspected contaminant migration, historically documented problem areas, the canal proper, and several relatively undisturbed areas.

After the preliminary data were collected and reduced, an interim report was prepared. The results of each method were evaluated by GCA and EPA to determine the most effective strategy for Phase II. Seismic methods were found to be inappropriate for the site conditions and therefore not continued in Phase II.

The surveys were then continued over selected areas for a more refined definition of the subsurface profile. Survey results were also used in determining potential areas for locating drill sites as well as screening these areas for unknown objects.

Ground Water Modeling

Geotrans of Herndon, Virginia was selected to model both the shallow and deep aquifers identified in the Niagara Falls area. They reviewed existing hydrologic data, especially the work by Johnston (1964). The regional and site specific geology was evaluated and a two-dimensional model was selected. The historical data were used to calibrate the model and additional data were made available by the other geotechnical contractors.

The data requirements for predicting flow rates and directions were discussed and the aquifer test strategy planned. Geotrans assisted JRB in the design and implementation of the aquifer tests. The tests included slug tests in seven shallow bore holes, packer tests at 10 ft intervals to identify permeable zones and short and long term pump tests to measure draw down and determine if any interconnection between aquifers existed. The hydrologic data were then reduced, plotted, and calculations performed to predict migration.

Well Drilling

The well drilling contract was awarded to Empire Soils of Orchard Park, New York. The driller was required to provide the necessary equipment and materials to complete the anticipated 245 wells in 8 weeks. It was estimated that a maximum of 10 drill rigs would be required to be in operation to meet the scheduling requirements. It was later determined to limit the extent of drilling to 178 wells.

Those wells constructed outside the restricted area were completed to just below the ground surface and housed in concrete vaults flush with the surface. The wells completed within the fenced area were completed with at least 3 ft steel riser pipes. All of the wells were provided with locking caps.

Land Surveying

A subcontract was issued by Empire Soils to Rene Sanvageam of Niagara Falls, New York to survey the well locations. For horizontal control the wells were tied into Niagara Falls city datum to an accuracy of $\pm$01 in. The locations were then converted to state planar coordinates and plotted on a 1 in. to 200 ft scale map. Vertical control was established to an accuracy of

0.001 in. The elevations were determined relative to mean sea level and were surveyed to the top of casing, ground level, and several control points along Cayuga and Bergholtz creeks and the Little Niagara River.

ROLE OF GCA

Due to the complexity of conducting field investigations with numerous subcontractors, it was necessary for GCA to provide an onsite coordinator for geotechnical activities. GCA was primarily responsible for interfacing EPAs study requirements with the subcontractors. GCA's field office became a central clearinghouse for pertinent information. Data which were acquired by the field activities or outside research was promptly distributed to ensure a high degree of performance. Examples of this type of data include: aerial photographs, local and regional maps, and state planar coordinates for all the sampling sites.

Drillsite Procurement

EPA provided GCA with a list of potential drillsites based partially on th "base" sites previously established by EPA for the overall sampling program. Additional sites were selected on the basis of availability, geologic data, the location of swales, and numerous request sites. GCA reviewed this list with EPA, JRB and Geotrans for additional site recommendations. After obtaining concurrence from EPA on drillsite locations, GCA issued drilling authorizations to JRB. Written authorization forms to enter private property and install monitoring wells was obtained by GCA. Properties belonging to the City of Niagara Falls were authorized for drilling by the Mayor's Office through the EPA. State properties required special permits which GCA obtained through the Department of Transportation, Department of Environmental Conservation, and the Urban Development Corporation.

A cooperative agreement was made between GCA, EPA, and the State of New York whereby well logs were made available to the state in exchange for permission to drill. At the completion of the project, a number of wells were released to the State and the remainder were grouted and abandoned.

After the proper authorization was obtained for a given drillsite, a special form (Figure 5-1) was filled out by GCA to tabulate pertinent drillsite information which was distributed to JRB and EPA.

Prior to drilling at any of the sites, GCA contacted the following utilities for clearance:

- Niagara-Mohawk
- New York Telephone
- National Fuel

GCA/TECHNOLOGY DIVISION

## DRILLSITE SELECTION

Location:

Owner:

Address:

Telephone:

Permission: Date:

Clearance: NY Telephone--

Niagara-Mohawk--

National Fuel--

Niagara Falls--Water Dept.

Sewer Dept.

Other--

Selection Criteria:

Comments:

Drillsite Number: _____

Strata: _____

Site Code: _____

Coordinates: E _____

N _____

Elevation: _____

Well Type: _____

No. of Wells: _____

Drill Dates--Begin

Complete:

Approval:

Date:

Figure 5-1. Drillsite information form.

- Niagara Falls Water Department
- Niagara Falls Sewer Department

Each drillsite was also screened by JRB using a metal detector to locate any buried objects.

TOC/TOX Analytical Data

Preliminary ground water samples were collected by JRB and delivered to the GCA Sample Bank. These samples were analyzed by Advanced Environmental Systems in Niagara Falls, New York within 24 hours of sampling. The TOC/TOX values were used to characterize future ground water samples which may require special handling required by the Department of Transportation for shipping.

TOX values were selected as the criteria for handling the well cuttings (sediment and rock fragments) as hazardous materials.

The EPA (Ada) determined that a level of 500 ppm or greater would constitute a hazardous substance. All well cuttings were drummed and labelled for storage until the TOX values were determined. Those well cuttings from which TOX values exceeded 500 ppm were disposed of as hazardous waste by CECOS International of Niagara Falls, New York.

Drilling fluids were contained in transfer trucks leased by Empire Soils. The fluids were filtered through a series of sand and diatomaceous earth filters before discharge into the Love Canal treatment plant collection system.

Special Sampling and Hydrology

At the request of EPA (Ada), two separate ground water sampling programs were conducted by GCA. Selected wells were resampled after extensive purging to confirm the existance of abnormally high pH readings.

The EPA also requested that additional hydrologic data from number of key wells. Continuous recorders were supplied by EPA and were operated for a 3 day period in November.

Data Evaluation and Reporting

After the completion of the field exploration phase of the geotechnical task, GCA outlined, reviewed, made recommendations, and approved the reports of the subcontractors. GCA also reviewed and evaluated the analytical data on ground water quality with EPA at the R. S. Kerr Research Laboratory in Ada, Oklahoma.

## SECTION 6

## ANALYSIS

The magnitude and diversity of the analytical program for the Love Canal Study required that a number of subcontractor laboratories be employed for its conduct. GCA was responsible for procuring such subcontractors, implementing the EPA analytical protocols, managing appropriate sample disbursement, and monitoring subcontractor analytical progress. These activities are described in some detail below.

### INTRODUCTION

The analytical portion of the Love Canal Study measured volatile organics,* pesticides, and metals in air; volatile organics, semivolatile organics, pesticides, and metals in water, soil, sediment, and biota; fluoride and nitrate in water; and additional parameters in ground water only. Analytical protocols and required internal QC measures were provided by EPA. These analytical methods are briefly stated below. Full analytical and QC procedures can be found in Appendix B to the Project QA Plan.

The analysis of the Tenax cartridges for volatile organics in air was accomplished by thermal desorption, cryogenic trapping and capillary column gas chromatography/mass spectrometry (GC/MS). The polyurethane foam plugs were extracted with 5 percent ether in hexane and, following column chromatographic cleanup, analyzed for pesticides in air by electron capture-gas chromatography (EC-GC). Analytical confirmation was by GC/MS. The hi-vol filters were analyzed for metals in air by inductively coupled plasma (ICP) and neutron activation analysis (NAA) by EMSL/RTP.

Water samples were analyzed by Methods 624, 625 and 608 for volatile organics, semivolatile organics and pesticides, respectively. Analysis for metals was by ICP or Atomic Absorption Spectroscopy (AAS) except that AAS was required for mercury and selenium. In addition, ground water samples were analyzed for Total Organic Carbon (TOC) and Total Organic Halides (TOX) and their pH and conductivity were measured.

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*Refer to Appendix A (pp. A-2) for compound hit lists and explanation of terms used for compound classes.

The soil and sediment samples were analyzed for volatile organics with a modification of Method 624 for purgeables. In this analysis, a soil or sediment sample was placed in the purge chamber, a prescribed amount of organic-free water was added, and the sample purged for 12 minutes. The sample was then analyzed by the standard purge and trap GC/MS system used in Method 624.

The analysis of soils and sediments for semivolatiles was not so straight forward in that a methods evaluation needed to be conducted on 48 samples to determine which of three available procedures would produce the best results. The data from these first 48 samples were evaluated by EPA and discussed with GCA in order to determine the most suitable protocol to be used for the remainder of the program. The selected method consisted of extraction using an homogenization apparatus. Samples were extracted with pH11 and then pH2 methylene chloride to obtain the base/neutral and acid extractables, respectively. After concentration of the extracts, an aliquot of each was taken to form a combined extract. The combined fraction was then analyzed by capillary column GC/MS.

Pesticide analysis of soils and sediments required sample preparation methods specific to each medium. For soils, a soxhlet extraction with acetone-hexane was followed by extract concentration and successive cleanup by aluminum oxide and Florisil columns. The sediment extraction procedure used column elution with 1:1 acetone:hexane, washing with water, and extraction of the pesticides from the water by methylene chloride in hexane. In both cases, the analysis of the extracted pesticides was accomplished using Method 608 (EC-GC). The priority pollutant metals in soils and sediments were determined by AAS after an acid digestion.

Various biota samples were analyzed for organic and inorganic species of interest to the Love Canal Study. Biological materials, specifically mice, worms, and crayfish, were analyzed for semivolatile organics and pesticides using both GC/Hall and GC/MS after appropriate digestion and extraction procedures. Potatoes and oatmeal placed at the sampling sites were designated as "foodstuffs" and analyzed for volatile organic compounds. The analytical method consisted of enclosing the sample with an acid solution in a septum vial, digesting the sample to generate a headspace sample within the vial, and analyzing the headspace for the hitlist compounds by GC/Hall. Metals were measured in vegetation by ICP and AAS after acid digestion and in hair by AAS, also after acid digestion.

## SUBCONTRACTOR SELECTION

### Understanding Program Requirements and Bid Package Preparation

The initial work performed by GCA involved the familiarization of GCA staff with the methodology requirements and the stage of development of the program. This activity entailed a series of meetings with the various EPA groups during the period of 9 July to 19 July 1980. It became clear very early on that the methods were, with some exceptions, very near implementation

and that GCA's role was to execute the program using the analytical methods specified by EPA and to obtain data consistent with the capabilities of the methods. Our objective then was to document the analytical methods and EPA-required quality control measures in sufficient detail that bid packages and, subsequently, analytical procedures manuals could be prepared.

In order to prepare the bid packages, GCA staff consulted with the responsible EPA personnel or their designees for each medium to be addressed. Brief summaries of the results of these consultations and specific problem areas are given below for each medium.

Air--

EMSL/RTP had responsibility for the volatile organics and trace metals and HERL/RTP had responsibility for semivolatile organics in air. Because EMSL/RTP elected to perform the trace metal analyses in-house, no subcontractors were solicited for these analyses. For the organic species, each EPA lab provided a list of targeted compounds (see Appendix A, Tables A-1 and A-2) and protocols for the analyses outlining both the methodology to be used and the quality assurance requirements. GCA developed, in conjunction with the EPA* labs, the instrument performance specifications and the type and amount of quality control necessary to meet the QA requirements. These performance specifications and QC requirements were incorporated into the appropriate analytical protocols; the number of QA samples to be analyzed was added to the field sample totals to obtain the number of samples requiring analysis. The volatile organic analyses were designated as Task I and the semivolatile requirements as Task II of the bid package.

Crucial to this issue of organics in air analysis was the provision of the specified collection media. Because the sampling effort was to commence immediately, in order to meet the time constraints of the program, the solicitation of competitive bids for this portion of the program was precluded. This fact was fully recognized by both EPA labs involved. Therefore, GCA solicited, in each collection medium, bids from organizations recommended by the EPA labs** and proceeded to let sole source subcontracts to these organizations for the preparation of the collection media. PEDCo Environmental was subcontracted to perform preliminary cleanup on the Tenax resin and to prepare sampling cartridges. SWRI was subcontracted to perform cleanup on the PUFs.

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*For the volatile compounds collected on Tenax, the staff of RTI was also consulted (vida post).

**The recommendations made by EPA were, in the opinions of the responsible GCA staff, clearly as qualified as any laboratories that could have been solicited for the media preparation tasks.

The procurement of the collection media differed for volatiles and semivolatiles. Because HERL/RTP had a sufficient quantity of PUF plugs for the collection of semivolatile organics, no external procurement need existed; this medium was simply supplied to the selected subcontractor. For the volatile organics, GCA elected to procure a sufficient quantity of Tenax and to provide the required amount to the selected subcontractor.

Water--

A hit list of compounds was developed by the responsible EPA laboratories. This list included the "priority pollutant" compounds and several nonpriority pollutant species that were suspected to be present in the area. (See Table A-3 in Appendix A.) The Federal Register (FR) methods (Methods 624, 625, 608) were specified as the analytical protocols for organic compounds and the ICP option for the metals.

Prior to commencement of the program, it was recognized by EPA that all compounds on the hit list were not amenable to analysis by the specified FR procedures. To address these problems, EPA provided a statement of the problems and recommended solutions as footnotes to the compound hit list. The problems that needed resolution are listed in Table 6.1. For items 1 and 6 (acrolein and acrylonitrile and benzidine), the alternate analytical methods would be used for quantitation if Method 624 or Method 625, respectively, detected their presence. Items 2 and 3 (N-nitrosodimethylamine and hexachlocyclopentadiene) would be resolved by the use of fused silica capillary column methodology. For items 4 and 5 (1,2-diphenylhydrazine and N-nitrosodiphenylamine), the indicated reporting procedure would be used. Because all samples were being analyzed by Method 608 for pesticides and PCBs, the 608 extracts would be available for GC/MS analysis. This additional specification was added to the protocols; i.e., if Method 608 compounds were observed, at concentration levels observable by GC/MS, then GC/MS confirmation of their presence was required.

In order to detect compounds of potential interest that were not included on the list, the requirement to identify, for each sample, up to 20 additional compounds present at relative concentrations above a specified level was added to the protocols. Finally, for reasons of cost-effectiveness, it was desired to perform the GC/MS analysis of Method 625 compounds by combining the acid and base/neutral extracts into a single sample; also, for compounds that partition into both the acid and base/neutral extracts, higher quality data would result when extracts were combined. Because existing data indicated that the fused silica capillary column methodology was capable of the resolution required, the combination procedure was added to the protocols as an option. This option would be exercised only after additional data were collected and deemed satisfactory. The additional data would be generated by each subcontractor analyzing the first 15 samples using both combined and individual extracts.

TABLE 6.1. PROBLEM COMPOUNDS

1. Acrolein and Acrylonitrile

These compounds may be observed to about 1 milligram per liter with Method 624. If detected the quantitative analysis must be accomplished by purging a second aliquot of the sample at 85°C as described in Method 603.

2. N-nitrosodimethylamine

This compound is not resolved from the solvent with the standard columns required for Method 625. It may be resolved with a 30 meter fused silica SE 54 capillary column.

3. Hexachlorocyclopentadiene

This compound decomposes in the injection port at the temperature required for Method 625. A second injection at a low injection port temperature is required to observe this compound when using the standard Method 625 columns. However, this compound is sufficiently stable for analysis with the 30 meter fused silica SE 54 capillary column.

4. 1,2-diphenylhydrazine

This compound decomposes in the GC injection port to azobenzene, and cannot be distinguished from it by 70 eV mass spectrometry. If observed it must be reported as 1,2-diphenylhydrazine or azobenzene.

5. N-nitrosodiphenylamine

This compound decomposes in the GC injection port to diphenylamine, and cannot be distinguished from it by 70 eV mass spectrometry. If observed it must be reported as N-nitrosodiphenylamine or diphenylamine.

6. Benzidine

This compound is decomposed during the solvent concentration and drying steps of Method 625. It may be observed, but the concentration measurement cannot be considered reliable. It must be confirmed using an alternative method such as Method 605 (Federal Register, December 3, 1979).

7. Alpha-, Beta-, Gamma-, and Delta-BHC, Endosulfan I&II, and Endrin

These compounds are sensitive to the pH=12 extraction conditions of Method 625 and are not observed under normal conditions. These compounds must be measured using Method 608 with confirmation by GC/MS using the Method 608 extracts.

It was GCA's responsibility to incorporate the modifications and additional specifications required to meet the program needs and provide written procedures. As for the air media, the quality control measures necessary to monitor control limits and to characterize the quality of the resulting data were determined in conjunction with EPA and these requirements were added to the bid packages.

In addition, GCA assumed the responsibility of procuring certain materials to be supplied to the subcontractors; the materials supplied to the subcontractors will be discussed in more detail in the following sections.

Soils and Sediments--

EMSL/LV was the EPA laboratory responsible for the soil and sediment analytical protocols. The list of compounds targeted for analysis was the same as the water list. The methods selected for these analyses were basically modifications of the 624, 625 and 608 methods for organics. Standard preparation procedures with an atomic absorption analytical finish were selected for the metal analyses.

It was recognized by EPA, at the outset of the program, that specifying procedures adequate for the preparation of soil and sediment samples for organic analysis was problematic because no standard, or even widely accepted, protocols existed. For this reason, EPA requested that a method study be conducted as part of the program. In order to conduct this study, EPA provided three procedures to be evaluated. These procedures would be evaluated by analyzing the first 50 samples (40 soils and 10 sediments) by all three procedures. The data generated from this study would be provided to EPA in order to assist in selecting the method most appropriate to analyze the remainder of the samples. GCA documented these requirements and incorporated the study into the bid package as a separate task (designated as Task IV). The methods study was made a separate task principally to facilitate the bidding process and to allow evaluation of proposals in terms of the methods study experience of the individual offerors.

The analytical work required for the remainder of the organic analysis of soil and sediment samples was designated as Task V in the bid packages. Offerors interested in bidding Task V were required to provide individual bids for each of the three procedures. As for the other tasks, the internal quality control requirements were specified and the external quality control and quality assurance samples were added to the sample totals for bidding purposes.

As mentioned above, GCA assumed responsibility for providing to the selected subcontractors certain materials required to complete the program. These included:

- Fused Silica Capillary Columns
- Analytical Standards

- Internal Standards
- Surrogate Compounds
- Quality Control Samples

The specifications for and source of these materials were provided by the responsible EPA laboratories. GCA procured a sufficient number of narrow bore fused silica capillary columns (from the same production run) to provide each subcontractor with at least one column. GCA procured the internal standards and surrogate compounds and provided them to EMSL/LV for disbursement. Quality control samples (sealed ampules of concentrates) were provided to GCA by EMSL/CI for disbursement to the subcontractors. At the request of GCA, EMSL/LV (via the EPA standards repository) provided the analytical standards to the subcontractors.

As for the water samples, the option of analyzing the sample extracts by combining certain extracts was included in the bid packages. This led to several configurations to be bid upon because extract combinations, if any, would depend on the preparatory method selected. The extract combination decision was not made part of the methods study but was deferred until an extraction procedure was selected. If extract combination remained an option after determining the extraction procedure, then combined and uncombined extracts would be analyzed on a sufficient number of samples to make the decision.

Biota--

EMSL/LV had responsibility for the biota program. At the time the bid packages were being prepared, the design of the biota program was not specified. However, analytical procedures for semivolatile organics in specific biota were provided that were sufficient to obtain competitive bids. Therefore, the procedures were incorporated into the bid package along with the QC and QA requirements. The analytical effort for biota was designated Task VI.

## Bidders Conference

Because of the stringent time frame of the program, a formal CBD announcement of the subcontracting requirements could not be made. Therefore, GCA contacted a number of organizations potentially qualified to perform the analytical work and invited them to a bidders conference. We began with lists of potentially qualified companies provided by the EPA laboratories and supplemented these lists with other companies which we felt qualified. In addition, all organizations who gained knowledge, by whatever means, of the upcoming bidders conference were invited to participate. Table 6.2 lists these prospective bidders. GCA felt that a bidders conference was mandatory because of the time constraints which essentially precluded any extensions in bid response time for scope of work clarifications.

TABLE 6.2. PROSPECTIVE BIDDERS LIST

| Company | Attended bidders conference | Submitted proposal/bid |
|---|---|---|
| Acurex Corp.<br>485 Clyde Avenue<br>Mountain View, CA 94042 | Yes | Yes |
| Battelle Memorial Institute<br>505 Kings Avenue<br>Columbus, OH 43201 | Yes | Yes |
| California Analytical Labs<br>401 N. 161th Street<br>Sacramento, CA 95814 | Yes | Yes |
| Environmental Science & Engineering<br>P.O. Box ESE<br>Gainesville, FL 32604 | Yes | Yes |
| Geomet<br>15 Firstfield Road<br>Gaithersburg, MD 20760 | Yes | No |
| Gulf South Research Institute<br>P.O. Box 1177<br>New Iberia, LA 70560 | Yes | Yes |
| IIT Research Institute<br>10 West 35th Street<br>Chicago, IL 60616 | Yes | Yes |
| Jacobs Engineering (PJB)<br>251 S. Lake Avenue<br>Pasadena, CA 91101 | Yes | Yes |
| Midwest Research Institute<br>452 Volker Blvd.<br>Kansas City, MO 64110 | Yes | Yes |
| Radian Corporation<br>P.O. Box 9948<br>Austin, TX 78766 | Yes | Yes |

(continued)

TABLE 6.2 (continued)

| Company | Attended bidders conference | Submitted proposal/bid |
|---|---|---|
| PEDCO Environmental<br>11499 Chester Road<br>Cincinnati, OH 45246 | Yes | Yes |
| Systems Science Software<br>P.O. Box 1620<br>LaJolla, CA 92038 | Yes | No |
| Southwest Research Institute<br>P.O. Box 28510<br>5220 Culebra Road<br>San Antonio, TX 78284 | Yes | Yes |
| TRW<br>3 New England Executive Park<br>Burlington, MA 01803 | Yes | Yes |
| University Hygienic Lab<br>University of Iowa<br>Oakvale Campus<br>Iowa City, IA 52242 | No | No |
| Monsanto Research<br>Station B, Box 8<br>Dayton, OH 45407 | Yes | No |
| OH Materials<br>P.O. 1022<br>Findlay, OH 45840 | Yes | Yes |
| Science Applications, Inc.<br>464 Prospect Street<br>P.O. Box 2351<br>LaJolla, CA 92038 | Yes | Yes |
| ERCO<br>185 Alewife Brook Parkway<br>Cambridge, MA 02183 | Yes | Yes |

(continued)

TABLE 6.2 (continued)

| Company | Attended bidders conference | Submitted proposal/bid |
|---|---|---|
| Measurement Sciences Corp.<br>300 Garden City Plaza<br>Garden City, NY 11530 | Yes | Yes |
| Compuchem<br>A Division of Mead Corporation<br>5 Triangle Drive<br>Research Triangle Park, NC 27709 | No | Yes |
| Kemron Environmental Services<br>32740 Northwestern Highway<br>Farmington Hills, MI 48018 | No | Yes |
| Advanced Environmental Systems, Inc.<br>Monitoring and Support Laboratory<br>P.O. Box 165<br>Niagara Falls, NY 14304 | No | Yes |

A bidders conference was held on July 22, 1980. The conference was attended by representatives from 19 organizations as indicated in Table 6.2. Each organization was provided a copy of the RFP which included, for each task, a scope of work, a statement of the deliverables, and the procedures to be used. The scope of work was addressed in some detail verbally with reference to specific procedures and other points in order to introduce the program requirements to the potential offerors in enough detail to provoke specific questions.

The minutes of the conference were recorded by a qualified court recorder.

Proposal Evaluation

Proposals were received from 19 organizations as indicated in Table 6.2. One proposal was not accepted because it was received late (the following day). All proposals were received by GCA Contracts Administration where the technical and cost proposals were separated. After receiving all proposals, the technical portions were provided to the technical staff for review.

The technical proposal review was conducted in three phases. Each phase of review focused on one or more of the proposal review criteria set forth in the RFP package. These criteria are listed in Table 6.3. First, the proposals were reviewed in terms of their responsiveness, in general, to all criteria. This overall evaluation emphasized quality assurance management and experience in the analysis of environmental samples. All bidders that (1) failed to provide a description of their QA/QC program, (2) did not have experience in the analysis of environmental samples and (3) did not delineate their management approach were eliminated. This phase resulted in the elimination of three offerors.

The second phase of the review dealt with determining the specific qualifications of the offeror versus the individual tasks they bid. In order to be considered further as a candidate for a specific task, the offeror must have had experience with the specified method, have the necessary facilities and equipment (except those to be provided by GCA), and have the qualified personnel required. This phase of the review resulted in a listing of potential subcontractors grouped according to "task qualified for."

In the third phase, the capacities and the preferences (statements of preference were solicited) of the qualified offerors were considered. Some offerors were qualified for more than one task but stated a preference of a particular task and/or stated the impact on their ability to perform a task if awarded certain other tasks. Finally, while some offerors were qualified to perform certain tasks, the quantity of analyses bid was very small compared to the total program needs. These offerors were not eliminated from consideration; however, they would not be considered as prime candidates unless necessary to meet the program requirements. The data from this phase were used to construct matrices of possible award configurations.

TABLE 6.3. TECHNICAL EVALUATION CRITERIA

Responses to the subject RFP will be evaluated using the following equally weighted criteria:

I. Offeror's immediate availability to initiate analysis, ability to respond on short notice with sufficient analytical personnel, and ability to complete the sample analysis program by 30 November 1980. The demonstrated analysis throughput of each laboratory will be one measure of these abilities.

II. Offeror's Quality Assurance/Quality Control Plan.

III. Offeror's experience in analyzing environmental pollutants in air, water, soils, sediment and biota, as appropriate to your bid.

IV. Offeror's availability of appropriate instrumentation and other facilities required to complete the program.

V. Offeror's proposed overall program management including qualifications of assigned personnel; i.e., experience, capability, and percentage of effort devoted to the program.

Next, the cost proposal data were added to the configuration matrices developed from the technical review. At this point an analytical program configuration that was believed to be in the best interest of GCA and EPA was constructed. It should be noted that in the recommended configuration, the offerors would not receive as many samples as their stated capacity but rather, in most cases, about 50 percent of the stated capacity.

Recommendations to EPA and Contract Awards

GCA staff presented the recommended configuration to EPA on August 6, 1980. The presentation was made in a series of meetings at RTP and by conference call. Representatives from EMSL/RTP and HERL/RTP (air media), ERL/Ada, Oklahoma (ground water), and EMSL/CI (water QA) attended the meetings.

In addition to the data used to construct recommended configuration, all information resulting from the evaluation was made available to the responsible EPA staff. One offeror in the air analysis area was questioned by EPA. EPA staff indicated a problem with this offeror's lab that surfaced during previous work at Love Canal. The problem was clearly defined and involved the offeror's failure to adequately prepare the sampling medium. Because this offeror would not be preparing the sampling medium and because he was qualified to perform the analytical task, it was agreed that his selection would not be detrimental to the program.

The presentation of GCA recommendations was then made to EMSL/LV, via a conference call, regarding their program responsibilities. Again one offeror was questioned as to his ability to deliver on schedule. GCA explained that this offeror had been explicit and emphatic in his proposal regarding the issue of capacity. Nevertheless, EPA directed GCA to visit this offeror's facility and if, as a result of the visit, GCA remained convinced of his ability to deliver on schedule, then the offeror would be acceptable. The visit was conducted and it was concluded that the offeror was definitely capable of performing on schedule.

The meetings resulted in approval of GCA recommendations. The subcontracts were then negotiated and prepared for EPA Contracts' approval and bilateral execution. At this point the analytical program was configured as shown in Table 6.4. The subcontract with MRI was not finalized until later in the program; i.e., after final selection of the biota media and the analytical methods to be used. Also, SWRI's subcontract was subsequently modified to include a portion of the biota analyses (trace metals in biota and volatile organics in foodstuffs) and Task VII.

After some problems emerged with one of the subcontractors (vida post), a subcontract was negotiated with TRW, Inc. of Redondo Beach, CA for the analysis of water samples. In addition, several sole source subcontracts were let based on EPA recommendations and additional program requirements. Research Triangle Institute (RTI) was subcontracted to prepare spiked standard and QC Tenax cartridges for use in the air monitoring program. As an

TABLE 6.4. ANALYTICAL PROGRAM CONFIGURATION

| Subcontractor | I | II | III | IV | V | VI | VII |
|---|---|---|---|---|---|---|---|
| Acurex Corp. | | | X | X | X | | |
| Battelle | X | | | | | | |
| CompuChem | | | X | | X | | |
| ERCO | | | | | | | X |
| GSRI | | X | X | | X | | |
| MRI | | | | | | X | |
| PEDCO[a] | X | | | | | | |
| PJB | | | X | | X | | X |
| SWRI[b] | | X | | X | X | | |

[a]PEDCO was also selected to prepare the Tenax sampling media.

[b]SWRI was also selected to prepare the PUF sampling media.

additional check on the Tenax QA/QC, IIT Research Institute (IITRI) was subcontracted to analyze a number of the standard and spiked Tenax cartridges using independent calibration. Advanced Environmental Systems (AES) was subcontracted to perform TOC, TOX, pH, and conductivity measurements on ground water samples prior to their shipment from the Sample Bank so that highly dangerous samples could be appropriately handled. AES was chosen, in part, because of their location in Niagara Falls, NY. The final analytical subcontractor, Wright State University (WSU), was chosen to perform dioxin analyses in all media. WSU was recommended by HERL/RTP, which directed the dioxin study, because they were known to be experienced in the analysis of dioxin-containing samples, had a high resolution mass spectrometer for use in this program, and demonstrated a safety program adequate for the handling of dioxins. This brought the total number of subcontractors to 14 organizations involved in the analytical portion of the program.

PROGRAM MANAGEMENT

The role of GCA in establishing and conducting the analytical program of the Love Canal Study is described below for each medium. Despite its seeming to be a rather routine matter of passing on information from one organization to another, the time constraints placed on project start-up and the need to coordinate activities of 5 EPA laboratories, 12 analytical subcontractors and 2 analytical QA subcontractors proved hectic in the early weeks of the program. Many of the internal QC measures and control limits were finalized as subcontracts were being prepared and required considerable discussion with EPA personnel, the potential subcontractors and members of GCA's analytical staff. After all analytical and quality control procedures had been established and the program was underway, similar discussions occurred if analytical subcontractors or EPA noted chronic problems with a measurement or sample type. Substantial effort was dedicated to keeping the subcontractors apprised of analytical problems encountered by other laboratories which were relevant to their own activities on this project. Likewise, EPA personnel were informed of analytical problems requiring their action and, as necessary, were updated on current progress of the subcontractors.

GCA technical staff members maintained project notebooks documenting their activities on the Love Canal Study. Excerpts from these notebooks giving examples of actions taken by GCA are given below. It is expected that these examples will serve to highlight some of the more important aspects of GCA's involvement in the study and will demonstrate the variety of activities conducted in fulfilling the needs of so diverse a study.

Air--

The monitoring program for ambient air samples collected in the Love Canal area was designed to provide information on three types of chemical substances. Each general class of pollutants* required its own specific sample collection method resulting in three distinct sample types, each with a prescribed method of analysis and differing QC requirements. In addition, QC requirements were specified by the EPA laboratories involved in the air monitoring program. As stated before, volatile organic compounds were

collected on Tenax-GC resin and their monitoring was the responsibility of EMSL/RTP. Pesticides and related compounds were collected on polyurethane foam plugs in a segment of the program supervised by HERL/RTP, and metals were monitored on hi-vol filter samples under the direction of another group at EMSL/RTP. These three groups designated different degrees and areas of responsibility to GCA for the performance of the air monitoring program.

Tenax cartridges--Selected volatile organic species were measured in ambient air as part of the Love Canal Study. Samples were collected by drawing specified volumes of air through glass cartridges packed with Tenax-GC. Analysis of these cartridges, or traps, was then accomplished by thermally desorbing the Tenax into a GC/MS system for quantitation and identification of the specified compounds.

GCA's role in the implementation and day-to-day management of this program consisted of collection and subsequent distribution of the analytical data and monitoring the internal QC data. As previously discussed, GCA, in consultation with technical personnel from EMSL/RTP, selected subcontractors for sample analysis, Tenax preparation, and QA activities. These subcontractors and their roles were as follows:

- Research Triangle Institute (RTI) prepared standard calibration cartridges as well as blind quality assurance spiked traps. RTI was also responsible for checking background level contamination of trap batches.

- PEDCo Environmental was selected as an analytical subcontractor. PEDCo was also responsible for preparing the traps by first cleaning the Tenax and then packing the tubes and checking each batch of tubes for background contamination.

- Battelle Columbus Laboratories was selected as an analytical subcontractor.

- IIT Research Institute (IITRI) was chosen to perform analyses on calibration and check traps for accuracy and precision.

At a meeting in Research Triangle Park on 26 September 1980, a discussion of problems associated with the analyses was held. Attending the meeting were representatives from EPA, GCA, Battelle Columbus Laboratories, PEDCo Environmental, and Research Triangle Institute. Problems in shipping, broken traps, benzene and toluene contamination of the Tenax, and problems with meeting QC criteria, especially by Battelle, were discussed. Resolution of some of these problems was accomplished as described below.

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*Refer to Appendix A (pp. A-2) for compound hit lists and explanation of terms used for compound classes.

To ensure compliance with column performance specifications, PEDCo was to purchase a capillary column from Battelle. Also, GCA was to inform its sampling subcontractor to pack traps more securely in their culture tubes after sampling. This resulted in a drop in the breakage rate, although some inevitable damage still occurred.

Problems with low levels of benzene and toluene contamination of the Tenax (approximately 20 ng/tube) continued throughout the program. QC monitoring of one batch of tubes (PEI-O) resulted in the recleaning of the batch because of high contamination levels. It was determined that low levels of contamination could not be prevented. In addition, because contaminant levels were observed to rise with the age of the tube, strict monitoring of the 30-day limit between tube preparation and analysis was observed.

It was also determined at the meeting that GCA would find another analytical subcontractor to perform analysis on standard and check traps to determine their precision and accuracy. In early October 1980, GCA contacted IIT Research Institute requesting quotes on analytical services to include the analysis of nine traps (six standards and three quality assurance traps). IITRI was not to be notified of concentrations of compounds in the traps, rather, they were to set up calibrations using their own systems and to quantitate versus these calibrations. In this manner, a check would be made on the standards preparation. GCA amended the contract of RTI to provide a redistribution of QA and standard traps to facilitate this test. This effort resulted in the external verification of 3 batches of spiked tubes (from a total of 12 batches). Results of these analyses were to be submitted to GCA within 7 days of the analysis and forwarded to EMSL/RTP. IITRI was selected as subcontractor for this work and received their first set of samples on 28 October 1980.

GCA continued to monitor the quality control sample results for both subcontractors following onsite audits in October 1980. At the request of EMSL/RTP, results of all calibration check samples were submitted verbally as soon as available to GCA. After compilation and statistical analysis, these data were then relayed to EMSL/RTP where potential or existing problems were discussed. This compilation of data continued until the end of the program.

GCA distributed field samples to the subcontractor labs so as to prevent overloading and to enable the labs to meet the stringent time compliance requisites for the analysis. As previously mentioned, monitoring of analysis dates was necessary due to contaminant levels. GCA established a schedule involving tube preparation, background determination, standard tube spiking, sampling, and analysis. Using chain of custody and shipping documentation, each batch of tubes was monitored to ensure that all traps were sent to the analytical laboratories no more than 10 days after preparation and were analyzed within 20 days of receipt.

GCA also served as an informational intermediary for EPA, gathering such data as spiking techniques for both standards and internal standards, specifics on tube preparation, levels of contaminants, and quantitative techniques. Problems encountered by the subcontracting laboratories were relayed through GCA to EPA, and, when required, followed up by GCA personnel and resolved in consultation with EMSL/RTP. For example, PEDCo had analyzed several tubes with high enough concentrations of a compound to cause instrument shutdown. After consultation with EMSL/RTP, it was determined that the problem compound was water, which had been trapped on the tube during sampling. Visual examination of the problem tubes prior to analysis had shown some moisture in the culture tubes enclosing the traps. A check of meteorological data from the sample date confirmed high humidity. To rectify the problem, it was decided that any traps showing condensation would first be dried in the culture tubes with sodium sulfate. No further problems of this sort were encountered.

Finally, GCA was requested by EMSL/RTP to obtain data on absolute area counts for internal standards spiked onto each sample tube by the subcontracting laboratories. Battelle had submitted this as part of its data package, and a slight modification to the computerized data reading algorithm allowed this listing. PEDCo, however, had not included these data and a further subcontract was awarded to complete this listing.

Polyurethane foam plugs (PUFs)--The analytical procedure for pesticides in polyurethane foam plugs was initially provided to the subcontracting laboratories in the Appendices to the analytical RFP. This method package had been obtained from HERL/RTP, the EPA laboratory responsible for this program area. It included extraction, concentration, clean-up and EC-GC procedures but did not address the specifics of quality control. Extensive discussion was required to establish a QC program which would be satisfactory to the goals of HERL and the overall project and which could also be reasonably met by the analytical subcontractors. One of GCA's analytical QC coordinators was responsible for initiating this discussion with HERL and, as necessary and as requested by HERL, obtaining input from the PUF subcontractors regarding reasonable frequency and control limits. While the ultimate decision for this area of the study was made by HERL, the subcontracting laboratories also were involved in designing the internal QC program. GCA served as a mediator and was responsible for all parties involved having correct and complete information. This series of information exchanges culminated in correspondence from HERL/RTP to GCA on August 27, 1980. This memorandum served to clarify and confirm internal QC procedures for the polyurethane foam plugs analyses. Summaries of entries in Notebook No. 1-619-026-124 of the Analytical QC Coordinator responsible for establishing and implementing this area of the program, illustrate GCA's role as follows:

| Date | Notebook Entry |
|---|---|
| 8/10/80 | This first entry regarding PUFs analysis was primarily an exchange of information within GCA. Ms. B. Myatt was preparing analytical protocols for inclusion in subcontract materials and needed the internal QC procedures thus far established by EPA-HERL in consultation with Dr. S. Zelenski of GCA. It was determined that one (1) method blank and one (1) spike recovery would be processed with each batch of extracts and that acceptable recovery ranges would be established by data collected in the Love Canal Study. |
| 8/12/80 | It was recognized that several items of QC specified in other protocols were not included in the PUFs analysis. These included standardization and calibration of the instrument(s), a list of compounds to be used in lab control standards (LCS) and the use of surrogates or replicates. A series of conversations were recorded between Ms. Myatt and Dr. Zelenski, Merrill Jackson of HERL and Randall Watts of HERL. Details of the requisite QC operations were given and the QC protocol for inclusion in the PUFs subcontracts was delineated. |
| 8/22/80 | Some questions had arisen within GCA as to whether some of the internal QC requirements were too stringent (i.e., calibration check every 2 hours when only running one sample per hour by GC). Discussion with Dr. K. McGregor of GCA and Dr. R. Lewis of HERL led to Ms. Myatt's being asked to contact the two analytical subcontractors involved to get their opinions on appropriate calibration and standardization procedures to meet quality needs and also to be consistent with the sample throughput required. Also, analysis of phenols by HPLC had been approved in the RFP for this task but GCA was having difficulty obtaining the method which was still in the prepublication stage. If the subcontractors were not using the HPLC, it would be omitted from the analytical methods manual. |
| 8/22/80 and 8/25/80 | Telecons with Dr. E. McGovern of SWRI and Dr. R. Novak of GSRI were recorded. These communications summarized each laboratory's usual standardization procedures for GC and recorded their agreement to meet required instrument response and detection limits. Points were brought up (internal standard) which necessitated further discussion with HERL/RTP. |
| 8/26/80 | Telecons with R. Watts and M. Jackson of HERL and McGovern and Novak were recorded. Information was transmitted regarding achievable standard checks and possible compounds for internal standards. The subcontractors were contacted directly by HERL to finalize details. HERL was to call B. Myatt regarding the resolution. |

8/27/80 R. Watts of HERL called B. Myatt to give final standardization procedures and QC limits. The HPLC method was released and assigned an EPA report number, and correction factors for compound collection efficiency were transmitted. The memorandum cited above was written and sent to GCA as confirmation of the finalized procedures. It included the PUF sampling and HPLC analytical procedures. M. Jackson of HERL was contacted regarding shipment of standard compounds to the two subcontractors. Appropriate chain of custody forms were sent to him, and the addresses to which materials were to be sent were transmitted.

This documented the set-up of the internal QC program for analysis of air samples collected on polyurethane foam plugs. Following this start-up and implementation, GCA's role in the PUFs analysis became one of managing sample distribution and analysis and acting as go-between for questions initiated by EPA or the subcontracting laboratories. Very few questions arose in these analyses.

Hi-Vol filters--The analysis of hi-vol filters for selected metals was an area of the Love Canal Study under complete control of the EPA laboratory (EMSL/RTP). This program was not subcontracted through GCA but was conducted totally by EMSL/RTP. GCA requested that, for the sake of completeness, the analytical procedures and appropriate QC measures be provided for inclusion in Appendix B to the Project QA Plan. These were received from EPA and formatted to be compatible with Appendix B. Through a recently discovered oversight, the Neutron Activation Analysis procedure used for Arsenic was not included. However, a written analytical procedure was followed and is included in Appendix A to this Final Report. Data sheets and a Coding Manual were provided to the EPA analytical laboratory so that results could be included in the Love Canal Study data base.

Water--

The water monitoring program for the Love Canal Study was performed under the direction of several EPA laboratories and included the analysis of sump, ground, drinking, sewer, and surface waters for selected parameters and pollutant classes. The analytical and QC procedures were specified by these EPA laboratories and were incorporated into analytical subcontracts and Appendix B by GCA. Radioactivity measurements were made by EMSL/LV and did not involve GCA. However, the radioactivity procedure was supplied to GCA for inclusion in Appendix B for the sake of completeness of the manual. The measurement of volatile organics, semivolatile organics, pesticides, metals, and the anions, fluoride and nitrate, was conducted according to a protocol developed primarily by EMSL/Cincinnati, although EMSL/LV also played a role in determining analysis and QC. Total organic carbon (TOC), total organic halogens (TOX), pH and conductivity were performed only on ground water samples as directed by the R. S. Kerr Laboratory, ERL/Ada. Selected samples were analyzed for TCDD as specified by HERL/RTP.

The role of GCA in the water monitoring program was primarily to combine the analytical and QC procedures provided by EPA into a comprehensive package for use by the subcontracting laboratories. As necessary, GCA fielded questions from EPA or the subcontractors and obtained answers from the appropriate parties involved. Several examples of these problems, resolutions and contract management are given below:

| Date | Notebook Entry |
|---|---|
| 8/13/80 | Many of the subcontracts pertaining to water analysis were sent out to the appropriate analytical laboratories. The procedures and internal QC protocol were those specified by EMSL in several documents (memoranda, draft reports) given to GCA. |
| 8/18/80 | K. McGregor of GCA met with EMSL scientists regarding methods clarifications. Surrogate compounds, internal standards and LCS compounds were specified, and comments on the methods documents that were in the subcontracts were taken for incorporation into final protocols. |
| 8/21/80 | K. McGregor met with M. Kozik and B. Myatt of GCA to instruct them to make these changes. Of significance was the change in analysis of selenium and arsenic. The original methods called for selenium by ICP and arsenic by flameless AAS. The final methods reversed these two elemental analyses. In addition, the analysis of soil/sediment by ICP was no longer permitted; only AAS could be used for soil/sediment samples. |
| 9/2/80 | The updated methods packages were distributed to analytical subcontractors, as appropriate. |

| Date | Notebook Entry |
|---|---|
| 8/4/80 | B. Myatt was requested by R. M. Ellersick to call ERL/Ada for the analytical and QC procedures for TOC and TOX. |
| 8/5/80 | B. Myatt had telecon with Craig Shew of ERL/Ada. TOC was to be performed by the standard EPA Method from EPA-600/4-79-020. TOX was defined as titratable chloride, similar to TOC. Shew believed that the subcontractor, AES, was using a Dohrmann apparatus and suggested that AES be contacted directly for their procedure. |
| 8/5/80 | B. Myatt contacted AES to request a copy of their TOX procedure. The document was received 8/10/80. |
| 8/26/80 | R. M. Bradway and B. Myatt discussed which samples required TOC and TOX analyses and Optional Forms 60 were requested from AES prior to preparation of the subcontracts. |

8/29/80 The analytical subcontracts for TOC and TOX were transmitted to AES.

10/15/80 R. M. Ellersick of GCA questioned the standardization procedure AES was using for the TOX analyzer after discussion with G. Smith of ERL/Ada. She requested that further information on recommended procedures be obtained from Dohrmann.

10/17/80 B. Myatt spoke with John Whitechurch of Dohrmann who judged that the AES procedures seemed to be acceptable. This information, along with Dohrmann's prescribed standardization and analytical procedures, was transmitted to R. M. Ellersick.

10/21/80 R. M. Ellersick prepared a memo reporting the follow-up to the original QA audit of the TOX Subcontractor. Four points of TOX standardization were listed. Three had been followed by the subcontractor since the beginning of the program. The fourth, which consisted of correcting data for percent recovery by the analyzer, would be followed from this date on. GCA would correct data already submitted.

2/25/81 Corrective Action Request Form No. LC-1-619-026-024 by R. M. Ellersick details events surrounding AES correction of data submitted prior to 10/21/80. Corrections were in error and considerable communication was required with the subcontractor, Dohrmann and GCA before final data were obtained and verified.

| Date | Notebook Entry |
|---|---|
| 9/9/80 | B. Myatt received telecon from K. Hausknecht of ERCO regarding water samples received for inorganic analyses. The internal QC program required that the first 10 samples of each type of water be spiked with known amounts of the elements of interest to determine if interferences were present. The first batch of samples received by ERCO did not have any identification of water type (i.e., sump, sewer, drinking), thereby delaying the start of the analytical program.<br><br>R. M. Ellersick was notified and informed the Sample Bank to note water type on sample tags from this point on and to call the laboratories which had received samples to give them sample type information on those samples already received. |

GCA's role in the water monitoring program was again primarily to implement the analytical and QC protocols specified by several EPA laboratories. This often required numerous discussions to clarify details of analytical methods and control limits for internal QC. Data reports were sent directly from the analytical subcontractors to the appropriate EPA laboratories concurrently with subcontractor submission of data to GCA. GCA acted as go-between for EPA and subcontractor questions and comments but did not review data for quality.

Soil/Sediment--

Soil and sediment samples were analyzed in a program directed by EMSL/LV. Compounds and elements measured by analytical subcontractors included volatile, semivolatile, and pesticide organics, metals and TCDD. Prior to the performance of the complete Love Canal Study, a methods evaluation program was conducted for semivolatile organics. GCA was responsible for setting up the analytical and internal QC protocols for all methods in the evaluation based on EPA requirements. Subcontracts were then written so that two laboratories (Acurex and SWRI) were involved in the evaluation and an additional three (PJB, GSRI and Compuchem) were subcontracted to perform the analyses by the method chosen. GCA managed both phases of this program. All decisions regarding the method of choice and the quality of analytical data were ultimately made by EMSL/LV in concert with GCA. As described for other media, the GCA role was one of coordination between EPA and the analytical subcontractors. An example of GCA's involvement in this program area is given below:

| Date | Notebook Entry |
|---|---|
| 10/7/80 | GCA received a call from D. Sauter of EMSL/LV requesting that data from one of the analytical subcontractors be evaluated for quality since results for several samples were suspiciously low in organic compounds. One of GCA's senior organic chemists (G. T. Hunt) was requested to pursue this matter. |
| 10/9/80 | G. Hunt submitted memo to R. Bradway and K. McGregor summarizing Sauter's comments on the data and his own review of the data package. He also documented a telecon to the subcontractor laboratory and his recommendations for further investigation. |
| 10/10/80 | R. M. Ellersick memo to R. Bradway and K. McGregor summarized actions to be taken regarding the data from this laboratory. These included obtaining surrogate recovery data from other analytical subcontractors and possibly scheduling a site visit to the laboratory in question. |
| 10/16/80 | A meeting was held at EMSL/LV and was attended by K. McGregor and G. Hunt of GCA and several EMSL/LV staff members involved in the Love Canal Study. Its purpose was to determine what actions should be taken regarding the problem laboratory. Foremost was to perform an onsite audit of the laboratory to establish whether the data in question were, in fact, unacceptable. In addition, the timely redistribution of this laboratory's sample load (should it be necessary) and treatment of data thusfar submitted were discussed. |
| 10/17/80 | K. McGregor, G. Hunt and D. Sauter of EMSL/LV traveled to the suspect laboratory to discuss internal QC practices and problems they may have been having. |

10/21/80 G. Hunt memo to K. McGregor and R. Bradway summarizes the site visit, its conclusions, and actions to be taken thereon. The volatiles and pesticides data were judged acceptable. The semivolatile results were unacceptable and the subcontractor was requested to send one half of each semivolatile extract to GCA for further disposition. After demonstrating satisfactory performance on QC samples, the subcontractor was to rerun each of the 75 sample extracts thus far analyzed. No further samples would be sent to this laboratory until QC problems were rectified.

2/5/81 Corrective Action Request Form No. LC-1-619-026-020 by R. M. Ellersick documents this complete series of events. Extracts sent to GCA were to be retained and, if necessary, analyzed by GCA. The subcontractor was successful in providing acceptable QC data and reran the original 75 extracts, thereby eliminating the need for GCA to analyze these samples. No additional samples were sent to the subject laboratory because the program was completed by the time acceptable QC was proved.

In addition to the analysis of the volatile, semivolatile, and pesticide organics, and metals monitored by EMSL/LV, TCDD and radioactivity were measured in selected soil/sediment samples. As with the water medium, the TCDD measurements were performed by an analytical subcontractor in a program monitored by HERL/RTP. Similarly, radioactivity analyses were performed by EMSL/LV and the procedures submitted to GCA for inclusion in the procedures manual, Appendix B. GCA managed the TCDD subcontract but did not participate in data evaluation.

Biota--

The analysis of biological materials in the Love Canal Study was primarily the result of a program conducted under the direction of EMSL/LV. As in other media, GCA set up the analytical and internal QC protocols for subcontracts under the direction of the EPA laboratory. GCA then served as manager of the subcontracts, fielding EPA and laboratory questions on analysis and data reporting. During the course of the program, it was noted that isophorone was the major organic component observed in the biota samples. Because acetone was used in the procedure, GCA conducted an experimental program to determine the extent of artifactual formation of acetone derivatives during biota sample preparation. This study is described more fully below.

The original RFP from GCA to potential analytical subcontractors included the analysis of semivolatile and pesticide organics in animal tissue. Two methods were being considered and the decision on which to use was made by EPA prior to the preparation of subcontract documents. Internal QC procedures applied to these organic analyses consisted of general items such as GC/MS tuning and calibration, method blanks and replicates and additional activities specified by EMSL/LV (i.e., reagent purity verification and extraction efficiency testing). Additional QC data were generated by a study conducted

prior to the start of field sample analysis. MRI, the subcontractor chosen for the animal tissue analyses, was required to procure mice, crayfish, and earthworms from a local (Missouri) source and to use these animal tissues in a study of blank levels of the hit list compounds and recovery of selected compounds spiked into the tissues. The recovery program consisted of eight hit list compounds spiked into nine samples (three each of mice, worms, crayfish) at two concentration levels with analyses performed by the subcontract extraction method and GC/Hall. Data from the recovery study were used to set analytical control limit specifications.

The measurement of volatile organics in foodstuffs and metals in hair and vegetation samples was not included in the GCA RFP to analytical subcontractors. In the course of the Love Canal Study, these methods were finalized by EPA, the number of samples determined, and the details of internal QC set through numerous conversations with EMSL/LV. Prior to these subcontracts being let, GCA was instrumental in identifying omissions or inconsistencies in the internal QC requirements. One such situation is described in the example below.

| Date | Notebook Entry |
|---|---|
| 10/6/80 | B. Myatt, D. Chase and G. Hunt obtained information from GCA Contracts Office regarding the numbers of samples for inorganics in hair and vegetation and volatile organics in foodstuffs. Analytical procedures were verified through EMSL/LV and bids were solicited from available subcontractors. |
| 10/10/80 | B. Myatt received quote from one subcontractor and also spoke with Dr. S. Black, EMSL/LV, about the number of hair and vegetation samples currently planned for inorganic analyses and what internal QC would be required. The numbers of method blanks, spiked samples and LCS to be run with each batch of samples for inorganics were specified. In addition, external QA was determined to be conducted by extracts of several samples being split and one half of each sent to an EPA laboratory for concurrent analysis. |
| 10/15/80 | The analytical subcontract for inorganics in hair and vegetation was let based on the number of samples specified by Dr. S. Black. |
| 10/22/80 | The internal QC procedures for volatile organics in foodstuffs were discussed by B. Myatt and S. Black. Resolution was reached on surrogates, laboratory control standards and control limits. Internal standards were not applicable to the prescribed analytical procedure. A subcontract was issued for these analyses using the analytical and QC procedures determined this date. |

## ADDITIONAL RELATED ACTIVITIES

### Artifact Formation of Acetone Derivatives

In the spring of 1981, GCA conducted a study initiated by direction from the EPA to determine the extent of artifactual production of acetone derivatives during Soxhlet extraction of environmental samples. The results of this study included both theoretical and experimental data concerning the formation of acetone derivatives as well as data obtained from the examination of GC/MS results for the Love Canal biota samples for the presence of possibly artifactual acetone derivatives.

Initially, data from two biota samples analyzed by capillary GC/MS and found to contain significant levels of isophorone were examined for the presence of acetone derivatives and for verification of the presence of isophorone. The samples selected were B30039 (crayfish) and B30078 (mouse).

Subsequently, several experiments were performed simulating the conditions found in a Soxhlet extractor and measuring the production of isophorone. Several conclusions from the study were made, including

- Isophorone is formed in the soxhlet extraction of both acidic and basic purified sand in significant amounts.
- The mass spectral data from the biota samples indicated the presence of acetone derivatives such as mesityl oxide, diacetone alcohol, phorone and isophorone.

Most importantly, the very real possibility of isophorone production in the soxhlet extraction of the biota was raised. A summary report entitled Investigation of the Artifactual Formation of Acetone Derivatives in Biota Samples from the Love Canal Study was submitted by GCA to EMSL-Las Vegas in May 1981.

### Evaluation of GC/MS Data

In accordance with a request from the Love Canal Study Project Officer, GCA/Technology Division completed a limited study of mass spectral data from each of the laboratories performing organic analysis for the Love Canal Study. Since time and cost precluded extensive examination of all mass spectral data supplied, two analyses were selected from each laboratory for verification. Selection criteria for data to be verified were arbitrary but were influenced by several considerations, including:

- Levels of pollutants reported
- Number of compounds reported
- Toxicity of compounds reported

Using these criteria, two samples from each of the laboratories were chosen for examination. Included in this list were analyses representative of all sample types collected in the study.

The data were examined primarily to verify compound identifications. Quantitation of the substances found would have required data inputs not immediately available. The data required include such factors as:

- Amount of sample extracted
- Concentration volume of sample
- Internal standard spike level
- Instrument response factors
- Surrogate spiking levels

While these data can be made available through interpretation of laboratory notebooks, time constraints prohibited this process.

Upon completion of this task, a summary report, Verification of Selected Mass Spectral Data From the Love Canal Study, was submitted to the Office of Research and Development, U.S. EPA, Washington, D.C. in May 1981.

Subsequent to this report, in June 1981, GCA was requested by EPA to copy a number of GC/MS data files on magnetic tape which had been submitted to GCA by the various analytical subcontractors. Approximately 150 sample files were requested with about 75 percent of these being soil and sediment samples. Affiliated blanks, standards and calibration runs brought to 300 the total number of files to be transmitted to EPA. These files were to be copied and sent to EPA in the following manner:

- All data on water samples were sent to EMSL-Cincinnati.
- All data on soil and sediment samples were sent to EMSL-Las Vegas.

GCA's role was complicated by the late arrival of tapes from some subcontractors, but eventually all GC/MS data due under the program were received on magnetic tape. Other problems included the inability of GCA to copy files on volatile organic analyses from Gulf South Research Institute due to format incompatibilities, lost data due to magnetic tape anomalies, and various computer difficulties. GCA supplied all taped information possible, as well as data on site locations, strata and analytical procedures.

Transmittal of GC-ECD Data (Chromatograms) to EPA

In early August 1981, GCA was informed that EPA was to screen all samples analyzed by Method 608-S (soils and sediments) for pesticides and PCBs in an attempt to determine the possibility of tetrachlorodibenzodioxin (TCDD)

contamination. GCA was asked to submit all chromatograms of samples analyzed by this method with associated standard chromatograms. A total of 278 samples were analyzed via Method 608-S and all available chromatograms, with data report forms, were sent to EMSL-Las Vegas. GCA also checked into some problems and questions which EPA had discovered, such as the use of internal standards for identification and the lack of a DDT standard in PJB Laboratories standard solution.

In early December 1981, GCA received from EMSL/LV a list of 49 samples for which no chromatographic tracings had been submitted to EPA under the audit. These are accounted for in the following manner:

| | |
|---|---|
| Chromatograms sent to EMSL-LV but listed as missing | 8 |
| Radiation sample | 1 |
| Analyzed by EMSL-LV (no chromatogram received by GCA) | 1 |
| Semivolatile sample (no GC/ECD analysis) | 1 |
| Nonvalid sample number | 2 |
| Chromatograms not received by GCA from the subcontracting laboratories | 36 |

Further checking on the 36 missing chromatograms indicated the number of missing samples from each laboratory was:

- Accurex 25
- Compuchem 1
- GRSI 1
- SWRI 7
- PJB 2

Each laboratory with missing chromatograms was contacted and all claimed that all documentation had already been sent to GCA. EMSL/LV was notified of this and no further action was taken by GCA.

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## SECTION 7

## SAMPLE BANK

The Love Canal sample bank was established at a vacant Niagara Falls laboratory building. The Bell Aerospace/Textron-Wheatfield plant served as a convenient base for sample inventory and shipping. It is located approximately 1 mile northeast of the Canal area and convenient to the sampling areas, field office and Federal Express shipping facilities. A refrigerated truck and trailer were also used for sample bank operations. The truck was used to hold and transport samples from the field office to the sample bank. The trailer served as storage space for the samples at 4°C until properly processed for shipping. Both vehicles were kept locked at all times, accessible only GCA personnel. An additional large chest freezer was also kept for storing biota samples and ice for packing and shipping.

The building was under 24-hour guard and had limited access providing adequate security. It was equipped with a ventilated hood system, storage area, office space, and laboratory facilities, making this building a good location for the sample bank. In addition, the building was shared by an independent laboratory, Advanced Environmental Systems (AES), which was contracted to handle certain needs during the sampling campaign, providing chemicals, pipets, sample container cleaning, acid an organic waste disposal and analysis of pH and conductivity. An industrial waste service (CECOS) was also contracted to pick up wastes at the end of the field sampling operations.

The sample bank was established in order to receive, inventory, label, package and distribute the thousands of samples collected over the 3-month sampling program. Samples were delivered to the sample bank from the field office daily. All samples were logged into a Master Log Book as shown in Figure 7.1. The samples were assigned sample bank numbers and cross-checked for the proper information on sample tags, analytical tags and chain-of-custody forms.

Samples were then prepared for shipment to the appropriate laboratories using specific Department of Transportation (DOT) procedures for packaging. Under DOT Title 49, Code of Federal Regulations Parts 171-177, procedures for packing, labeling and shipping hazardous materials. Samples were shipped out in three categories, "environmental samples" (nonhazardous), "corrosive," and "poison B."

Most were shipped out in three categories, "environmental samples" (nonhazardous), "corrosive," and "poison B."

(Page 1 of 2)

MASTER LOG

| Sample bank No. | Date sample collected | Received on chain-of-custody No. | Sample Tag No. | Condition of sample | Stratum | Site code | Source of sample (Soil/SED/$H_2O$) | Designate composite/grab (Soil/SED/$H_2O$) | Depth (Soil/SED/$H_2O$) | Temp ($H_2O$ only) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Species (biota) | Designate composite/grab (biota) | | | |
| | | | | | | | Lot No. (air) | Designate occupied/unocc. (air) | Collection media (air) | Type of site (air) | Location of sample (air) |
| | | | | | | | | | | | |

| Date sample sent out | Analytical chain-of-custody No. | Analytical tag No. | Analytical lab ID | Type of analysis | Designate | | | Time | Sampler's initials | Comments | Signature of sample bank personnel |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Blank | QC | Sample | | | | |
| | | | | | | | | | | | |

(Page 2 of 2)

Figure 7.1. Sample page from master log.

Most soil, surfacewater, drinking water, groundwater and air samples fell into the environmental sample category. These samples were packaged and shipped to prevent breakage or leakage according to the National Enforcement Investigations Center (NEIC) recommendations. The samples were doublebagged and packed in metal surfaced Coleman coolers with "blue ice" packets to keep the samples at 4°C. Regular ice was used if "blue ice" was not available. The cooler drainage holes were taped shut in case a sample leaked into the melting ice.

Some groundwater samples were found to have a pH greater than 12. Under DOT classifications these samples are deemed "corrosive" and must be handled, packaged and shipped with special precautions. These groundwater samples were pH adjusted and shipped as environmental samples for all analyses except the semivolatiles and volatiles. These were packaged and shipped under DOT regulations for "corrosive" materials as follows. The doublebagged samples were placed in 1-gallon metal containers which in turn were packed in Coleman coolers with ice. The samples could be handled under the "limited quantities" DOT regulations because they were unanalyzed hazardous waste site samples. The total sample content of each cooler could not exceed 1 quart because of this restriction. The following labels were attached in compliance with the DOT regulations:

- "CORROSIVE"
- "CORROSIVE LIQUID - NOS"
- "LIMITED QUANTITY"
- "INSIDE CONTENTS COMPLY WITH DOT REGULATIONS"

In addition, a shipper's certification for hazardous materials was required to be completed and attached to the shipping container.

All sump water, sewer water, sediment samples and selected soil, surface water and ground water samples which were most lkely to contain TCDD, were packaged and shipped as "POISON B" samples. These samples also fit the "limited quantities" category. These samples were restricted to 1 quart or less per gallon container. Each sample was doublebagged, as the others, with the analytical sample tag between the bags. These samples were then packed in 1 gallon metal paint cans with sufficient packing material to prevent breakage. The metal cans were closed and taped shut. Each can was labeled:

- "POISON"
- "DANGER-PELIGRO"
- "FRAGILE-THIS SIDE UP"

These cans were placed in metal surfaced Coleman coolers with sufficient ice to keep the samples at 4°C during shipping and ethafoam to prevent shifting. The maximum allowable volume of "poison B" samples per cooler was 1 gallon. The coolers were labeled as follows:

- "POISON LIQUID-NOS"
- "LIMITED QUANTITIES"
- "INSIDE CONTENTS COMPLY WITH DOT REGULATIONS"

These samples were restricted to cargo-only aircraft and can only be sent by Federal Express on Monday, Wednesday and Friday. These samples also required a shippers certification form.

Biota samples were shipped and packed in dry ice to keep them frozen during shipping. If five (5) pounds of dry ice or less is used there are no restrictions on shipping other than a label indicating the amount of dry ice used. If more than 5 pounds is used then a shipper's certification form must be completed. All samples were shipped following strict chain-of-custody protocol.

The sample bank also served as a supplier for the sampling crew. It provided sample tags, custody forms, log books, evidence tape, locks, coolers, and clean sampling containers. Sample bank personnel also aided by precleaning and checking Tenax and polyurethane foam plugs and preweighing hi-vol filters for the air sampling campaigns.

Quality Assurance samples were also processed through the sample bank to the appropriate laboratories. The true values for the quality assurance samples were stored under lock and key at the sample bank or the EPA laboratory.

All sample data from the program was transferred from the sample bank to the GCA computer. Sample bank numbers, sample tag numbers, and site ID numbers were verified for every sample entered into the computer. Inventory was done to cross-check all samples, labels, custody forms and log books. Ten percent (10%) of the data was cross-verified for quality control purposes.

## SECTION 8

## DATA MANAGEMENT

### DATA HANDLING SYSTEM

The Love Canal software system was designed with the capacity to handle and store over 330,000 data records in three separate files. These were:

- Raw data
- Verified data
- Validated data

This section provides an overall description of the data system, including the inputs, the software, and the outputs. Details on each component in the system are provided in subsequent sections of this report.

#### The Data Flow System

Figure 8.1 presents a flow diagram of the data handling system which was developed for the study. The key features of this system include:

- Input of all data to the system via computer cards;
- Editors for all sample data, analysis data, and analysis verification action data cards entering the system;
- Maintenance of the raw data in multi-record card-image format;
- Storage of all disk files in the PANVALET Ⓣ file management system for security and ease of maintenance;
- Conversion of a completed sample to a single record at the verification level;
- Capability to produce data reports summarized by any field on the sample card;

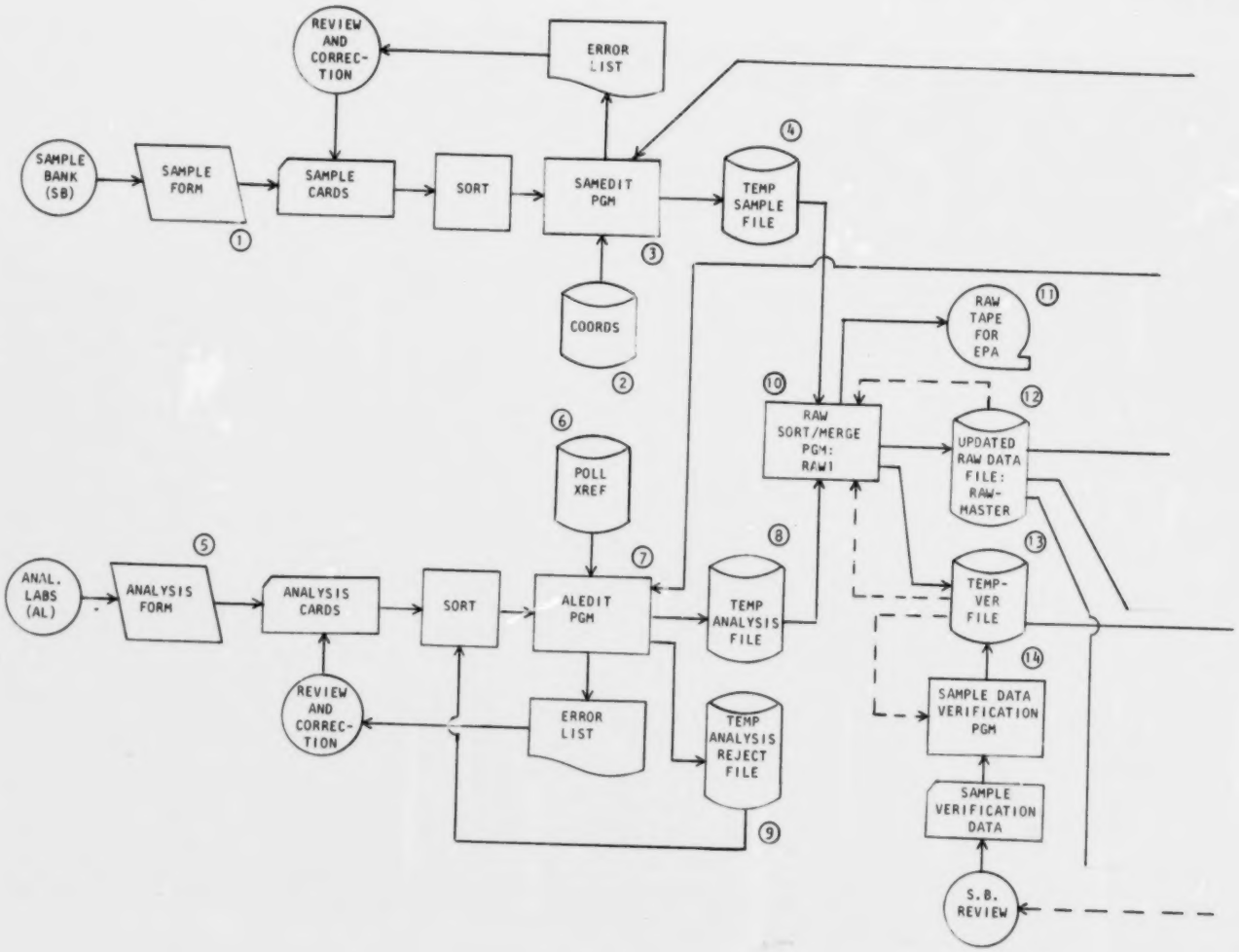


Figure 8.1. Data handling system flow diagram.

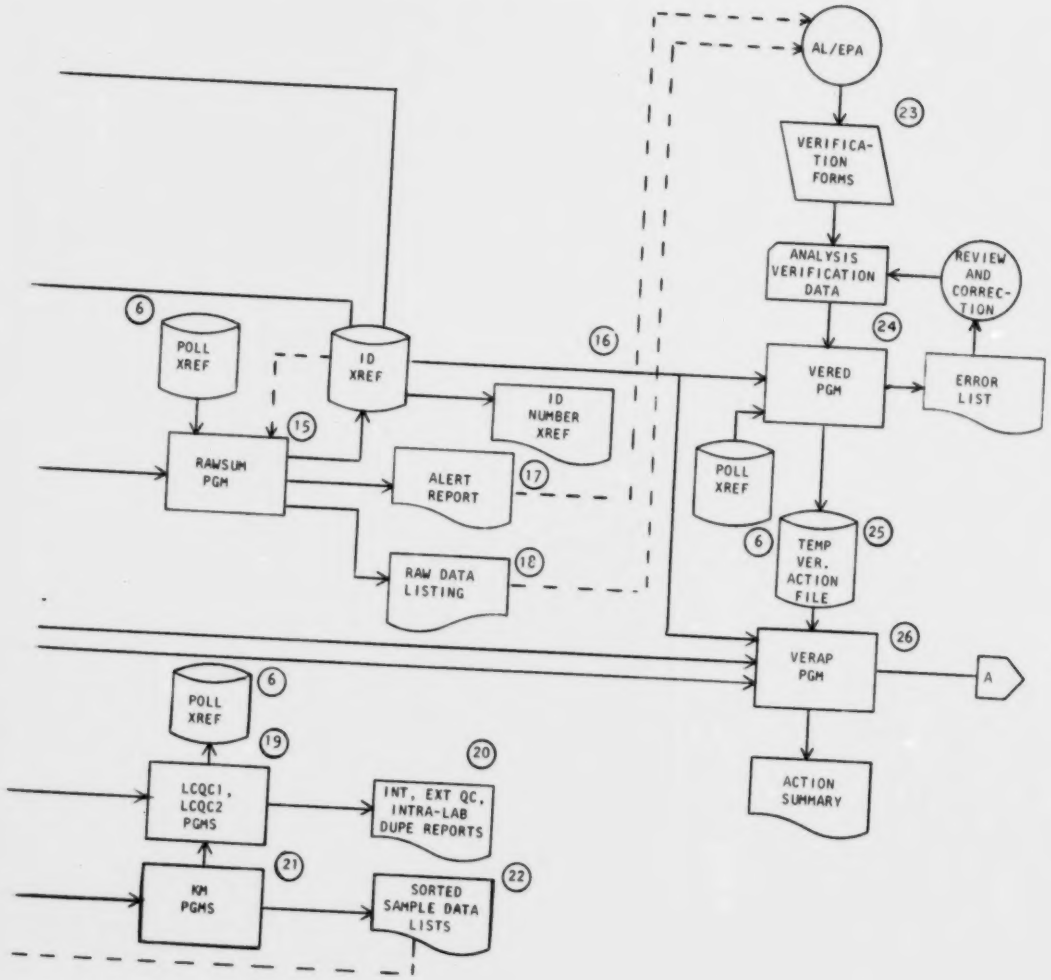


Figure 8.1 (continued).

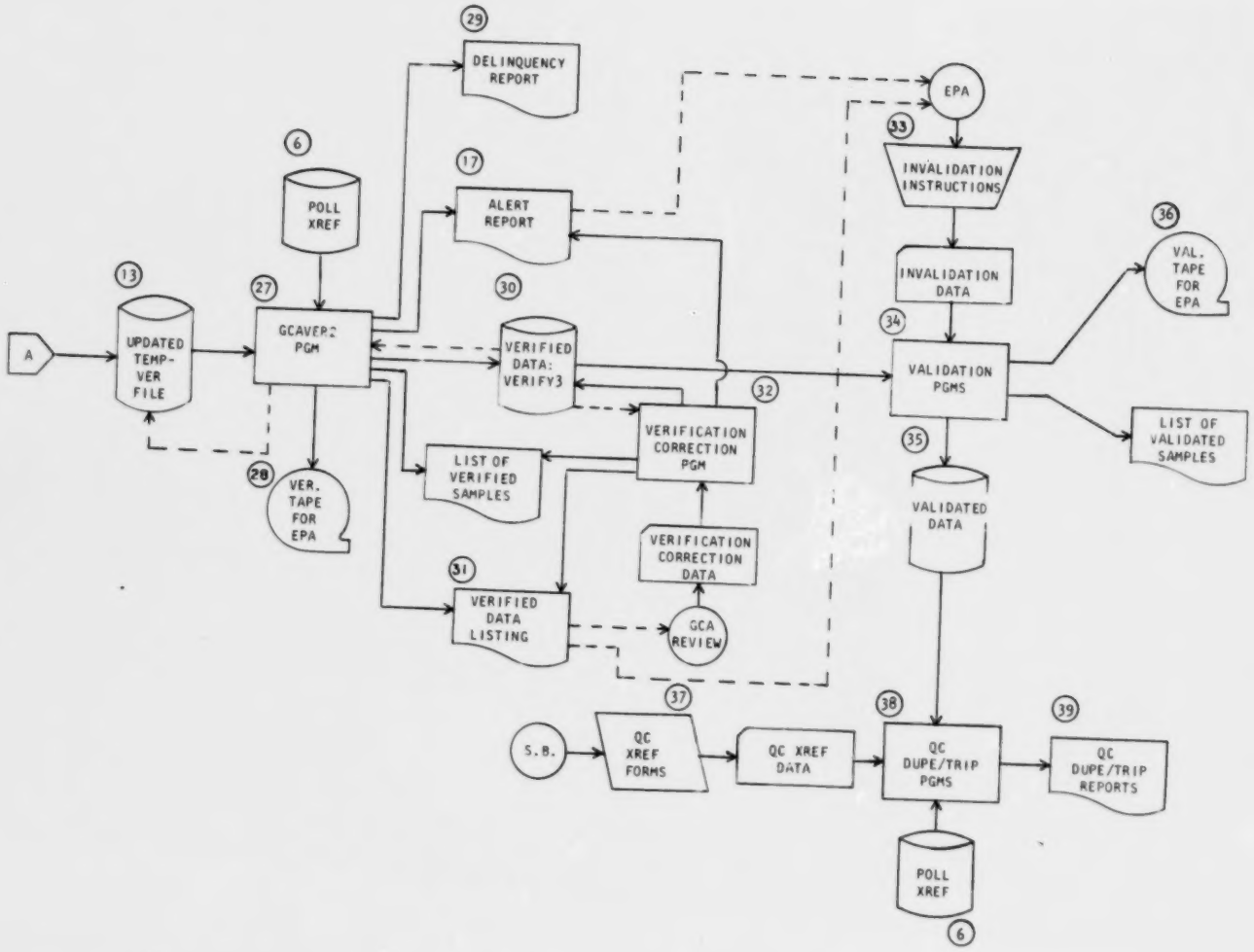


Figure 8.1 (continued).

- Generation of raw data tapes, verified data tapes, and a tape of validated data for use by EPA;

- Analyses of internal QC, external QC and duplicate/triplicate QC data.

Each significant processing step noted in Figure 8.1 is assigned a number. A brief description of each of these steps is given below.

1. The Sample Data Reporting Form was completed by GCA Sample Bank personnel and sent to GCA, Bedford, for keypunching and verification. It included information such as sample ID, location, date, time, source, instrument readings, and tag numbers.

2. The Coordinate Cross-Reference file (COORDS) was an on-line table of the state planar coordinates associated with each site ID in each stratum. These coordinates were inserted into the sample data record at the time of sample data editing. (This processing step was added to the system mid-way through the study.)

3. The Sample Data Edit (SAMEDIT) program checked all sample cards entering the system to ensure that mandatory fields were correctly supplied. (See Appendix D-1 for a list of checks made.) Any errors or omissions were flagged for review by GCA Data Management. The Julian date on which data were entered into the system was added to each record at this step.

4. The temporary sample file (SAMCARDS) was used to accumulate the edited sample data records prior to the periodic (more or less weekly) run which merged these data into the master raw data file.

5. The Analysis Data Reporting Forms were coded by the analytical laboratories (or in some instances by GCA Data Management), and were sent to GCA, Bedford, for keypunching and verification. They included concentrations of pollutants for field samples and QC samples, as well as analysis method, analysis date, and sample size.

6. The Pollutant Cross-Reference file (POLL XREF) contained information for each pollutant identified by EPA for study. It was used to check the validity of pollutant codes on analysis data forms, to label computer output, and to flag data entries with concentrations exceeding "alert levels" stored in the POLL XREF file.

7. The Analysis Data Edit (ALEDIT) program checked all analysis data cards to ensure that mandatory fields were correctly supplied. (See Appendices D-2 and D-3 for a list of edit checks.) The POLL XREF file was used to check that the pollutant codes on analysis data cards were valid. Errors or omissions were flagged for review by GCA. The Julian date on which data were entered into the system was added to each record at this step.

8. The temporary analysis data file (ALCARDS) was used to accumulate the edited analysis data records prior to the run which merged these data into the master raw data file.

9. The temporary analysis reject file (ALLCARDS.BAD) was used to set aside analysis data for which sample data were not yet present in the raw master file. Each time ALEDIT was run this file was updated.

10. The Raw Data sort/merge program (RAW1) sorted the edited sample data and analysis data and merged them into the raw data master file. The RAW1 program also generated a tape of raw data for EPA, and it added all new sample data to the Temporary Verification file (TEMPVER).

11. Each time the RAW1 program was run, a new tape of raw data was generated for EPA. One file contained all sample data added to the system since the previous RAW1 run, and a second file contained all new analytical data. The card-image format was maintained in these tapes.

12. The Raw Data file (RAWMASTER) contained all edited sample and analytical data, sorted by Sample ID, card type, and sequence number. This cumulative file preserved the card format in which the data were originally coded. The file was maintained by using the PANVALET data handling system.

13. The Temporary Verification (TEMPVER) file contained verified data in card-image format. Sample data were added to this file by the RAW1 program and were verified by the Sample Data Verification Program (description 14). Verified analysis data were added to TEMPVER by the VERAP program (description 26). The data in this file were deleted as the verified data file was updated with these same data.

14. The Sample Data Verification Program used the PANAVALET update process to correct the sample data in the Temporary Verification File (TEMPVER). Corrections were supplied by the GCA Sample Bank.

15. The RAWSUM program generated three reports (descriptions 16, 17, and 18 below) to allow review of the raw data. This review stage enabled laboratories to check their results as they were added to the system and to correct any errors in coding, interpretation, or transcription.

16. The ID Number Cross-Reference report listed all cross-reference numbers supplied on the sample cards, including the Sample ID, tag, and chain-of-custody data. The report included lists sorted by each of these numbers. The ID cross-reference information was also kept in a disk file (ID XREF) for checking the ID numbers of all new data entries. The Sample ID served as the basis for cataloging all the cross-reference numbers.

17. The Alert Report was a special listing in which all observations above a pre-determined level were printed so that special attention could be directed to the sampling site by GCA and EPA. At the raw data stage, the alert report was also used by Data Management to help in identifying outliers resulting from transcription or keypunch errors.

18. The Raw Data Reports listed sample data and analysis data for all samples for which analysis data had been entered into the system since the last listing. One part of this report listed all new data, sorted by Sample ID; this report was distributed to EPA and GCA. The second part of the report listed all analysis data and selected sample data, sorted by analytical laboratory; these reports were sent to the appropriate analytical laboratories for verification.

19. The Love Canal QC1 (LCQC1) program analyzed the recovery rates for internal and external QC samples, while the Love Canal QC2 (LCQC2) program compared results for laboratory-generated duplicates and their mates.

20. Reports generated by the LCQC1 and LCQC2 programs gave recovery rates by medium, analysis method, and laboratory, and listed pairs of results for laboratory-generated duplicates.

21. The eight KM programs were designed to sort the sample data on any field and to list selected data for review by GCA and EPA.

22. Different KM reports were used for different purposes. For example, listings sorted by site ID were used to monitor sample collection, and lists sorted by laboratory were used to monitor laboratory workload and response. Lists by sample tag number were used by the GCA Sample Bank to verify the sample data.

23. The Verification Action Reporting Forms were completed by GCA Data Management in response to the verification of the raw data listings by the analytical laboratories. Any changes to the raw analysis data were specified on these forms.

24. The Analysis Data Verification Edit (VERED) program checked all codes and functions included on the verification forms to ensure accuracy. At this stage, the legal functions were "Add," "Delete," and "Change." (See Appendix D-4 for a complete list of edit checks.)

25. The Temporary Verification Action file accumulated the analysis data changes for all the samples being verified in the current run. The contents of this file were deleted each time the VERAP (description 26) program was run.

26. The Verification Application (VERAP) program selected from the raw data file the analysis data for all samples being verified in this run, applied the indicated changes to them, and added these data to the TEMPVER file (description 13). (The raw data file was not altered in this process.)

27. The GCAVER2 procedure and its major program, VERFILE, selected from the TEMPVER file all samples with analysis data, and added them to the verified data file. In doing this, the program converted all the card-image records (both sample data and analysis data) for each sample into a single-record format. GCAVER2 also generated a tape of verified data for EPA, a cumulative list of all verified samples, and three other reports on the verified data (descriptions 17, 29, and 31).

28. Each time either the GCAVER2 procedure or the Verification Correction Program (description 32) was run, a tape was created for EPA which contained the verified data for all samples in the current run. All data for each sample were stored in a two-record format designed to meet EPA's specifications.

29. The delinquency report, generated by the VERFILE program, listed all samples for which analysis data were overdue. Identification of these samples was based on the date on which the sample data were entered into the system. Any sample remaining in the TEMPVER file for over 30 days, without accompanying analysis data being supplied, was included in the report.

30. The verified data file (VERIFY3) was created and updated by the GCAVER2 procedure. It was a cumulative file of all verified data, with the data for each sample being stored in a single variable-length record.

31. The Verified Data Listings were similar in format to the Raw Data Listings. One part of the verified data report was sorted by Sample ID, and the second part was sorted by sampling medium. Both parts of the report were sent to EPA for use in data validation. Included in these reports were all samples included in the current run of the GCAVER2 or Verification Correction programs.

32. The Verification Correction program used PANVALET update procedures to make corrections to the verified data file. This step was added to the data handling system when it became evident that changes and corrections were being submitted to, or identified by, GCA Data Management after samples had alreeady been verified. Either sample data or analysis data could be corrected by this procedure.

33. Invalidation instructions from EPA consisted of lists of samples or types of samples which were to be wholly or partially invalidated. Partial invalidation was typically based on laboratory, medium, analysis date, analysis method, and pollutant.

34. The Validation programs were developed to apply EPA's invalidation instructions. Partial invalidations were accomplished through PANVALET updates and through programmed identifications of pollutants. Samples which were wholly invalid were identified by Sample ID number.

35. The Validated data file was in the same format as the verified data file. It contained all data in the verified data base which had not been invalidated by EPA.

36. The Validated data tape for EPA was in the same format as EPA's tape of verified data. The tape contained all data in the verified data base which had not been invalidated by EPA.

37. The QC Cross-Reference (QC XREF) Reporting Forms, which contained the ID numbers of sets of duplicate and triplicate samples, were submitted by the Sample Bank as a means of identifying duplicate and triplicate samples generated by the Bank.

38. The QC Duplicate/Triplicate Analysis programs compared the analysis results obtained for each set of samples listed on the QC Cross-Reference Form.

39. The report on the QC Duplicate/Triplicate Analysis listed the results of the comparison of data on each set of samples on a pollutant-by-pollutant basis.

Data Flow Timetable

Table 8.1 summarizes the timetable for the flow of data through the raw data processing system for a typical sample. Elapsed time includes the time necessary for transmitting data from one activity site to another, as well as for producing or processing data at each site.

While many samples followed this timetable fairly closely, the flow of other samples deviated from it substantially. The major variations occurred in the time elapsed between sampling and the completion of the Sample Form. This affected the overall timetable only when the delay was 4 weeks or more (such delays were common for air samples, in particular). Further delays occurred when analysis results were not submitted by the laboratories within the specified time period.

GCA Data Management initially expected to be sending out verified data listings approximately 17 days after the raw data listings for the corresponding samples had been transmitted, or 59 days after sampling. This allowed 7 days for the laboratories to verify and transmit the raw data listings, 7 days for GCA to code and keypunch the Verification Action Forms and enter them into the system, and 3 days for GCA to create and transmit the Verified Data Listings and Alert Reports. In fact, the first Verified Listings were not sent out until December 20, which was 11 weeks after the

first set of raw data reports was sent out. Several factors contributed to this delay, including the fact that coordinates and other sample data were not verified until after the sampling program was completed and the Sample Bank had returned to GCA. The major factor, however, was the staggered submission of results by analytical laboratories. Because the results for many samples were submitted over a protracted period of time, it was hazardous to verify results too swiftly: more results might have been on the way.

TABLE 8.1. TIMETABLE FOR RAW DATA FLOW

| Days after sampling | Activity |
|---|---|
| 2 | Sample Bank completed Sample Form. |
| 3 | Sample Forms received at GCA. |
| 10 | Sample Forms keypunched and entered into data management system; ID Cross-Reference generated. |
| 32 | Analysis data forms received at GCA. |
| 39 | Analysis data keypunched and entered into system. |
| 42 | Raw data Listings and Alert Reports generated and transmitted. |

Because large volumes of samples were processed in the initial verification runs, the elapsed time between the transmittal of raw data reports and verified data reports was promptly cut to 4 weeks. By the end of January, this gap was narrowed to only 1 week.

Figure 8.2 shows the actual processing schedule which as achieved. The raw data portion of the graph is drawn for samples which were complete at the raw data stage; that is, they had both sample data and analysis data present. At any given time there were also incomplete raw data results in the system, waiting to be matched with the corresponding analysis data or sample date.

Figure 8.2 reflects the rate at which raw analysis data were received from the analytical laboratories. Results came in very slowly until mid-November; great quantities of results were received until mid-December and then the flow dwindled again. This bulge in receipt of raw analysis data shows up in Figure 8.2 as a bulge in complete raw samples processed between late November and late December. This bulge is repeated for the verified data about 1 month later.

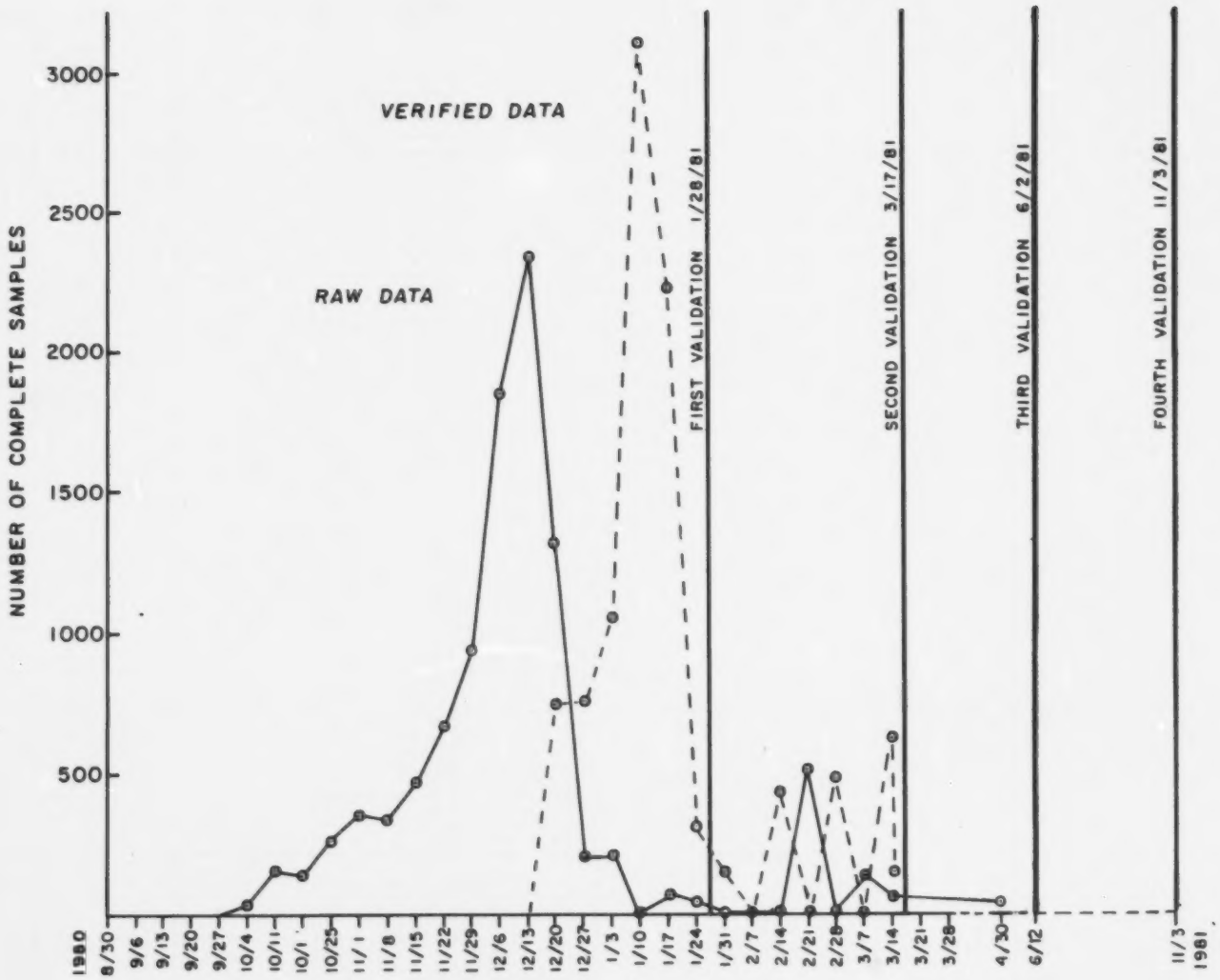


Figure 8.2. Actual data processing schedule.

Validation took place on four separate dates, January 28, March 17, June 2, and November 3, 1981. In each case, all samples verified through that date were passed through the validation programs.

### The Data Management Staff

Design and implementation of the data management system was accomplished by a staff of seven people at Bedford. While the staff worked as a team, and each member assisted with whatever tasks were currently pressing, each staff member also was responsible for one of the following roles:

- Data Manager
- Programmer
- Raw Data Processer
- Verification Coordinator
- Verification Data Processer
- Forms and Reports Clerk
- Keypuncher.

In addition, Data Management coordinated the coding of sample data at the Sample Bank, which was conducted by one full-time and two part-time coders, and which was supervised onsite by a Sample Bank member. Data Management also employed two part-time coders at Bedford to assist with sample data coding. During January 1981, when the major verification effort took place, the Data Management staff was further augmented by seven other people, most of whom had worked on the Love Canal Study during the earlier design and sampling phases.

## CODING FORMS AND PROCEDURES

### Coding Forms

Four basic types of data coding forms were required to report the sampling data. These included forms for:

- Sample Data--Sample Collection and Chain-of-Custody information, reported by the GCA Sample Bank;
- QC Cross-Reference Data--Sample ID numbers of sets of duplicate and triplicate samples, as designated by the Sample Bank;
- Analytical Data--Analytical results on field samples, external QC samples, and laboratory internal QC samples, reported by the analytical laboratories (several "subtypes" of analytical forms were designed, based on the type of analysis being reported); and

- Verification Action Data--Data changes submitted by the laboratories in response to computer listings of raw analysis data.

Because all data submitted were to be keypunched onto computer cards of 80 columns each for entry into the GCA computer, each form was divided into rows of 80 columns. Each row was assigned a "Card Type" code, which was precoded on the form. Sample data required six separate card types, while analytical data and verification action data each required five separate card types. The master sample ID number, as well as the card type, was entered on each row of coding, so that each computer card could be fully identified in terms of source of data and type of data.

A set of identification codes appeared at the top left corner of each reporting form. The parts of these codes were as follows:

| LC 1-619-026 - | - | - | - | - |
|---|---|---|---|---|
| Project number | Subcontractor document no. (appears only on analytical data forms) | Project form number | Form serial number | Page number |

The project number and project form number were precoded on the reporting forms. Individuals submitting the forms to GCA inserted the remaining numbers. The subcontractor document number was assigned to the laboratories by the GCA Quality Control Officer. Each coder also inserted a serial number on each code sheet, with each type of code sheet used by the coder being serialized separately over the course of the project. Because it was often necessary to fill out more than one code sheet of a particular type for a given sample and analysis method, a box was also provided for a page number.

Table 8.2 lists all the data reporting forms developed for the project. Included in the table are the subtypes of analytical data coding forms.

Each of these forms is exhibited in Appendix F. These exhibits represent the final format of each form. While most forms were developed in August 1980, some minor revisions were made to them during the course of the project. A few fields were added to or deleted from some analysis data reporting forms. The date of the final version of the form is given in the lower left corner. For forms submitted to GCA prior to the issuance of the final forms, entries were made or deleted by GCA Data Management to bring the coding on those forms into conformity with the final format. The form types are discussed in more detail in the sections which follow.

Sample Data Reporting Forms--

Only one type of coding form was used to report collection data and chain-of-custody data on samples handled by the Sample Bank. Performance Evaluation samples and External QC samples, as well as field samples, were reported on the "Sample Data Reporting Form" (see Appendix F).

## TABLE 8.2. LOVE CANAL DATA REPORTING FORMS

| Form No. | Card type(s) | Type of data | Form type | Form sub-type: Medium | Form sub-type: Compounds analyzed | Form sub-type: QC type |
|---|---|---|---|---|---|---|
| E01 | S1-S6 | Sample | Sample data | | | |
| E-2 | Q | QC cross-reference | QC cross-reference data | | | |
| J01 | A1 | Analysis | Analyte concentration | Any | Any compounds not pre-coded on forms J02-J10 | |
| J02 | A1 | Analysis | Analyte concentration | Air (Poly-foam) | Pesticides | |
| J03 | A1 | Analysis | Analyte concentration | Air (Tenax®) | Volatile organics | |
| J04 | A1 | Analysis | Analyte concentration | Water, soil, Sed., biota | Volatile organics | |
| J05 | A1 | Analysis | Analyte concentration | Water, soil, Sed., biota | Semivolatiles | |
| J06 | A1 | Analysis | Analyte concentration | Water, soil, Sed., biota | Pesticides and PCBs | |
| J07 | A1 | Analysis | Analyte concentration | Air (Hi-Vol), water, soil, Sed., biota | Inorganics-metals | |
| J08 | A1 | Analysis | Analyte concentration | Water | Inorganics-anions | |
| J09 | A1 | Analysis | Analyte concentration | Water | Special analysis--TOX, TOC | |
| J10 | A1 | Analysis | Analyte concentration | Water, soil, Sed. | Special analysis--dioxin, TCDD | |
| J11 | A2 | Analysis | Internal QC | Any | Any compounds not pre-coded on forms J12-J26 | Any |
| J12 | A2 | Analysis | Internal QC | Air (Poly-foam) | Pesticides | LCS |
| J13 | A2 | Analysis | Internal QC | Air (Tenax®) | Volatile organics | LCS |
| J14 | A2 | Analysis | Internal QC | Air (Hi-Vol), water, soil, Sed. | Inorganics-metals | LCS, spike |
| J15 | A2 | Analysis | Internal QC | Water | Volatile organics | LCS, spike |
| J16 Int. | A2 | Analysis | Internal QC | Water | Volatile organics | Surr.; Std. |
| J17 | A2 | Analysis | Internal QC | Water | Semivolatiles | LCS, spike |
| J18 Int. | A2 | Analysis | Internal QC | Water | Semivolatiles | Surr.; Std. |

(continued)

TABLE 8.2 (continued)

| Form No. | Card type(s) | Type of data | Form type | Form sub-type | | |
|---|---|---|---|---|---|---|
| | | | | Medium | Compounds analyzed | QC type |
| J19 | A2 | Analysis | Internal QC | Water | Pesticides | LCS, spike |
| J20 | A2 | Analysis | Internal QC | Water | Inorganics-anions | LCS, spike |
| J21 | A2 | Analysis | Internal QC | Soil, Sed. | Volatile organics | LCS, spike |
| J22 Int. | A2 | Analysis | Internal QC | Soil, Sed. | Volatile organics | Surr.; Std. |
| J23 | A2 | Analysis | Internal QC | Soil, Sed. | Semivolatiles | LCS, spike |
| J24 Int. | A2 | Analysis | Internal QC | Soil, Sed. | Semivolatiles | Surr.; Std. |
| J25 | A2 | Analysis | Internal QC | Soil, Sed. | Pesticides | LCS, spike |
| J26 | A2 | Analysis | Internal QC | Water, soil, Sed. | Special analysis | Any |
| J31 | A3 | Analysis | Qualitative analysis | Any | Semivolatiles by GS/MS | |
| J41 | A4 | Analysis | Comments | | | |
| J51 | V1 | Verification action | Analyte concentration | | | |
| J52 | V2 | Verification action | Internal QC | | | |
| J53 | V3 | Verifiction action | Qualitative analysis | | | |
| J54 | V4 | Verification action | Comment | | | |
| J55 | V0 | Verification action | External QC | | | |
| J60 | A0 | Analysis | External QC | | | |

Card S2: Flow Information (Air Samples Only)

- Start Flow
- End Flow
- Average Flow
- Duration
- Total Volume
- Pump ID Number

Card S3: Custody Data

- Preparer's ID Lot (Air only)
- Chain-of-Custody Numbers:
  - Preparer to Bank (Air only)
  - Bank to Sampler (Air only)
  - Sampler to Bank
  - Bank to Lab
  - Preparer to QC (Air QC only)
  - QC to Bank (QC only)
- Sample Tag
- Date Sent to Laboratory
- Analysis
- Well Number (Ground water only)

Card S4: Meteorological Data (Air Samples Only)

- Time
- Relative Humidity
- Temperature
- Wind Speed
- Wind Direction

(Above four fields repeated for each observation)

- Met. Station ID

- Sequence Number of Card

Card S5: QA/QC Comment (QA/QC Only)

- Comments entered to identify blanks, duplicates, triplicates, PE samples, and externally generated QC samples

- Sequence Number of Card

Card S6: Comments

- Any relevant comments about sample

- Planar Coordinates for surveyed sites

- Sequence Number of Card

Details on the information provided by the Sample Bank for each of the above data items is contained in Part I of the "Love Canal Study Coding Manual for Sample Data Reporting Forms, " which is reproduced in Appendix G. The manual also specifies which fields within each card type were mandatory under the various sampling conditions, including QA/QC sample preparation.

QC Cross-Reference Reporting Forms--

The QC Cross-Reference Reporting Form (see Appendix F) was used by the Sample Bank to identify sets of duplicate and triplicate field samples. These samples, collected as part of the QA/QC program, were identified on this reporting form by Sample ID number only. All other information about the samples was reported on the Sample Data Reporting Form. Only one Card Type (Q) was necessary for the QC Cross-Reference Reporting Form, since all information regarding a set of duplicate or triplicate samples was entered on one row on the coding form. The information coded included:

- Two sample IDs for a pair of duplicates or three sample IDs for a set of triplicates;

- Medium;

- Comments (optional).

Part II of the "Love Canal Study Coding Manual for Sample Data" (see Appendix G) contains information on the preparation of the QC Cross-Reference Reporting Form.

Analysis Data Reporting Forms--

GCA Data Management developed the Analysis Data Reporting Forms in close cooperation with those GCA staff members who were responsible for specifying the analytical procedures for the Love Canal Study. The analysis data were

reported on five separate types of forms: "Analyte Concentration" (Card Type A1); "Internal QC" (Card Type A2); "Qualitative Analysis" (Card Type A3); "Comments" (Card Type A4); and "External QC" (Card Type A0).

To facilitate coding, separate Analyte Concentration Forms (A1) and Internal QC Forms (A2) were developed for specific analysis methods, where possible. In these cases, the compounds to be analyzed were listed to the left of the coding rows, and their respective pollutant codes were precoded on the forms. Nine specific Analyte Concentration Forms (J02-J10), and fifteen specific Internal QC Forms (J12-J26) were developed. In some cases, the list of precoded compounds which might be identified during an analysis of a sample was quite long, and several coding sheets were needed for the complete lists. This was true for forms J03 through J06.

For each sample, columns 1-6 provided a unique identification. This information, together with the information in columns 7-32 (sample medium, analysis method, lab ID, analysis date, analysis time, and sample size), was entered once on each coding form for the sample and analysis method. Thus, each of the five types of coding forms (card types A0, A1, A2, A3, and A4) contained the same information in columns 1-32 for a particular sample and analysis method. When the data were keypunched, the information in columns 1-32 was punched on all cards for that sample and method.

The following information was entered on Analysis Data Reporting Forms:

<u>All A Card Types (A0-A4)</u>

- Sample ID
- Medium
- Method of Analysis
- Laboratory ID
- Date of Analysis
- Time of Analysis
- Sample Size

<u>Card Type A0: External QC</u>

- Pollutant Code
- Observed Concentration
- Expected Concentration (true value from EPA)
- Comments about Pollutant
- Sequence Number of Card

Card Type A1: Analyte Concentration

- Pollutant Code
- Concentration
- Method of Analysis Specific to Pollutant
- Not Detected/Trace/Qualitative Indicator
- Confirmation Indicator
- Percent Recovery (Dioxin only)
- Minimum Detectable Concentration (Dioxin only)
- Comments about Pollutant
- Sequence number of Card

Card Type A2: Internal QC

- Pollutant Code
- Observed Concentration
- Expected Concentration
- Method of Analysis Specific to Pollutant
- Internal Standard/LCS/Surrogate/Spike Indicator
- Percent Recovery (Dioxin only)
- Comments about Pollutant
- Sequence Number of Card

Card Type A3: Qualitative Analysis

- CAS No. or Descriptive Identification of Compound
- Match Score
- Analyst's Judgment of Identification
- Verification of Identification
- Comments about Pollutant
- Sequence Number of Card

Card Type A4: Comments

- Method Blank Associated with Sample
- Any other Relevant Comments about Sample
- Sequence Number of Card

The External QC Form (card type A0) was filled out for all external QC samples. The Analyte Concentration Form (card type A1) was filled out for all field samples and for internal QC method blank samples. The Internal QC Report Form (card type A2) was filled out for all other QC samples generated internally by the laboratory. It was also filled out to report the surrogates and internal standards which the analytical laboratories introduced into field samples. The Qualitative Analysis Form (card type A3) was not filled out for internal QC samples; it was completed only for analysis of semivolatile organic compounds in water, soil, and sediment samples. The Comment Form (card type A4) was required for all field samples, except Tenax samples, because it was used to report the method blank associated with each sample. The Comments form was also used to make comments about any samples, as deemed relevant by the analytical laboratories.

GCA Data Management coded the External QC data on Card Type A0, while the analytical laboratories were generally responsible for coding card types A1-A4. Analysis Reporting Forms were provided to the analytical laboratories as appropriate to their analysis responsibilities in the Love Canal Study.

Details on the analysis information provided by the analytical laboratories is contained in the "Love Canal Study Coding Manual for Analysis Data Reporting Forms," which is reproduced in Appendix G. This manual also specified which fields within each form or card type were mandatory under the various analysis situations.

Verification Action Reporting Forms--

Five basic types of Verification Action Forms (card types V0-V4) were developed, to correspond directly to the five basic types of Analysis Data Reporting Forms (card types A0-A4). Because these forms were used to enter corrections to analysis data, the format of the V cards was almost identical to the format of the corresponding A cards. The V cards, however, had one additional field; this was the Verification Action Code, in Column 72. This indicated whether the values entered in other columns represented additions, deletions, or changes.

Only those fields involved in the corrective action were coded on the Verification Forms; thus it happened only very rarely that all fields in a row of coding would be filled out. The following information ws coded:

- Sample ID
- Pollutant Code on Card Types V0, V1, or V2;
  or CAS No. on Card Type V3

- New Value (in any field or fields on form)

- Action Code (for Add, Delete, or Change)

Any number of Verification Action cards could be coded for a specific sample, and these might include all types of actions. The section of this report on Verification Procedures provides details on GCA's coding and use of these forms. It also describes coding for samples for which no corrective action was necessary.

Coding Manuals

GCA Data Management prepared coding manuals to guide the Sample Bank and the analytical laboratories in coding the Love Canal Reporting Forms for which they were responsible. Data Management staff consulted with GCA Sample Bank and analytical personnel throughout the preparation of the manuals. These manuals, which were issued first in August 1980, were updated periodically during the course of the project. The final versions of the "Love Canal Study Coding Manual for Sample Data Reporting Forms" and the "Love Canal Study Coding Manual for Analysis Data Reporting Forms" are reproduced in Appendix G.

Coding Manual Revisions--

Reasons for altering the coding manuals included:

- Addition of coding fields (e.g., "date to lab," "analysis," and "well number" on card type S3);

- Addition of codes for certain fields (e.g., addition of subcontracting laboratory codes);

- Deletion of codes for certain fields (e.g., deletion of method codes 625BC and 625DW on Analysis Data Reporting Forms);

- Change in coding units (e.g., change of water temperature from °F to °C);

- Change in coding requirements (e.g., number of meteorological observations required).

In general, a change in coding instructions did not insinuate that data coded according to the old instructions were incorrect. That is, alterations in coding instructions were generally issued at or before the first occurrence of the coding of the information involved in the change. For example, new laboratory ID codes were added when subcontracts were signed with the laboratories and before any samples had been sent to them; recording units for water temperature were changed to correspond to the units being measured in the field and recorded by the Sample Bank; and the "Well Number" field was added to the S3 card when the first ground water sample was coded.

In three instances, however, changes in coding procedures did necessitate changes in data already submitted to GCA and entered into the GCA raw data base. These changes were made by GCA Data Management through additional coding and computer programming. The first problem occurred when the "date to laboratory" and "analysis" fields were added to the S3 card after data processing had commenced. GCA's corrective action for the problem is described in the section below on preprocessing of sample data. The second problem occurred when it was realized that method codes 625BC and 625DW were ambiguous and would have to be altered to properly designate the methods used by the laboratories in analyzing the samples involved. GCA's corrective action for this problem is discussed in the section of this report on verification procedures. The final problem occurred when several compounds were deleted from the list of compounds which EPA wanted the laboratories to measure in the samples. The section on the verification edit program describes GCA's corrective action for this problem.

Use of the Coding Manuals--

The "Coding Manual for Sample Data" was designed to guide the GCA Sample Bank in its coding of the "Sample Data Reporting Form" (Form E01, for card types S1-S6), and the "QC Cross-Reference Reporting Forms" (Form E02, for card type Q).

The "Coding Manual for Analysis Data Reporting Forms" was designed to guide both EPA and subcontracting analytical laboratories in coding the "Analysis Data Reporting Forms." Forms covered by the manual were: Analyte Concentration Forms J01-J08; Internal QC Forms J11-J25; the Qualitative Analysis Form J31; and the Comments Form J41. Analysis Reporting Forms not covered in the coding manual were Special Analysis Analyte Concentration Forms J09 and J10, Special Analysis Internal QC Form J26, and the External QC Form J60, all of which were coded only by GCA Data Management. Similarly, no coding manual was prepard for the Verification Action Reporting Forms, since these also were coded only by GCA Data Management. Coding of all forms not covered in manuals is discussed below in the section on coding.

As well as serving as a guide for those responsible for coding information on sample data and analysis data, the coding manuals served as a reference for GCA and EPA staff who examined the data reported out by GCA Data Management. That is, the manuals provided the means for interpreting codes and for explaining the presence or absence of certain information under various circumstances.

For the Analysis Data Reporting Forms, the Analysis Data Coding Manual first provided instruction for coding columns 1-32, which contained the information which was keypunched on all Analysis cards (card types A0-A4). Then coding instructions were provided for each card type in turn, with the coding of each field being described for each card type. Similarly, for the Sample Data Reporting Form, the Sample Data Coding Manual first provided instructions for coding columns 1-10, which contained the information to be keypunched on all Sample Data Cards (card types S1-S6). Again, instructions were then given for each field on each card type. Finally, instructions were provided for coding each field on the QC Cross-Reference Reporting Form (card type Q).

The following categories of information were provided for each field on each card type:

- Applicability--specified the circumstances in which the code had to be entered;
- Recorded by--indicated the category of person responsible for recording or assigning the information;
- Description--described the field;
- Units--specified reporting units, when applicable;
- Coding Instructions--indicated the proper use of columns and characters, and gave acceptable codes;
- Examples--provided column-by-column examples.

## Coding Procedures

This section describes the coding of the Sample Data, QC Cross-Reference, and Analysis Data Reporting Forms. Coding of the Verification Action Reporting Forms is described in the discussion of Verification Procedures in a later section.

Sample Data Coding--

GCA Data Management had the overall responsibility for Sample Data coding. However, since most coding took place at the Sample Bank, a GCA Sample Bank staff member supervised coding onsite. Coding was done at the Sample Bank rather than at Bedford because log books and other written records maintained by the Sample Bank were the primary source of data, and onsite personnel with first-hand knowledge of field procedures were consulted continuously during the coding process.

GCA Data Management prepared the Sample Data Reporting Form and Coding Manual during August 1980, and one Data Management staff member traveled to the Sample Bank at the end of August to instruct the onsite supervisor in coding procedures. The supervisor then trained the coders, who were hired locally for this task. One full-time coder began work at the Sample Bank at the beginning of September, and two additional coders were hired in mid-October and worked for the last few weeks of operation of the Sample Bank at Love Canal. GCA Data Management conferred with the coding supervisor daily by telephone during this coding period, and on three occasions Data Management staff traveled to the Sample Bank to observe coding procedures, solve problems, and assist with coding.

Conceptually, the coding of sample data for water, soil, sediment, and biota samples was a straightforward process. All data to be coded, with the exception of planar coordinates and the depth of ground water samples, were to be coded directly from the Master Logs maintained by the Sample Bank. Planar

coordinates and ground water depths were maintained on cross-reference sheets. In practice, many exceptions to the normal process occurred. For example, log book entries were frequently incomplete, either because required data had not been supplied by the sampling technicians, or because Sample Bank personnel were too pressed for time to make all entries while packing samples for shipment to the laboratories. Particularly at the outset of the project, the coders often found that planar coordinates had not yet been plotted for the sites being sampled. In all these instances, coders had to set aside partially-completed code sheets until the information could be obtained, and the coding supervisor spent considerable time in locating the missing data. Changes which occurred during the coding process also interfered with efficient coding. For example, designations of site codes were altered for some sites near the beginning of the program and coders were required to go back through completed forms to make the necessary changes. (In some instances, these codes were changed back to their initial values, requiring yet another set of changes.)

Coding of air samples was more complex and more fraught with problems. Many data items required on the coding forms were not entered in the log books and had to be located from other sources. In addition to making one-for-one entries from log book to code sheet, and looking up the planar coordinates from a reference sheet as was done for other samples, the coders had to perform these extra steps for air samples:

- Refer to incoming chain-of-custody records to obtain the preparer's lot number and the Preparer-to-Bank (or QC-to-Bank) chain-of-custody number.

- Refer to Bank-to-Sampler chain-of-custody records to obtain this custody data item.

- Refer to flow data sheet (provided by sampler) to obtain the air pump number, start flow, and end flow for the sample, based on the sampling date, site ID, and location at site.

- For indoor samples, refer to the "sample data sheet" (one sheet per sample provided by the sampler) to obtain meteorological readings.

- For outdoor samples (and for indoor samples with missing information on the sample data sheet), refer to meteorological data sheet (provided by the sampler) to obtain meteorological readings.

- Derive relative humidity from wet/dry temperature readings, if not derived by sampler.

- Convert temperature readings from °F to °C, if not converted by sampler.

- Identify duplicate samples by finding log entries for "livingroom 1" (L1) and "livingroom 2" (L2) for the same date, stratum, site ID, and sampling medium.

coders at the Sample Bank concurrently with the coding of the Sample Data Reporting Forms. That is, it was intended that, as duplicate and triplicate samples were encountered and coded, entries would immediately be made on the QC form. However, because of the press of time and because incomplete log book entries made it difficult to identify sets of samples, the coding of the QC Cross-Reference sheets was postponed until all Sample Data coding was complete. (In fact, these data were not needed until late in the project, since they were used in a computer program which accessed the verified or validated data files rather than the raw data file.)

Coding of the QC Cross-Reference Reporting Form was done by the Coding Supervisor, who examined each log book to identify sets of duplicate and triplicate samples. For water, soil, sediment, and biota samples, the identification was made directly from notes in the "comments" column in the log book. Here the duplicate and triplicate status of the sample was recorded, along with the sample tag number of other members of the set. For air samples, identification was made just as it was when the Sample Data Reporting Forms were completed. That is, duplicates were identified by finding "L1" and "L2" entries for the same sampling date, site ID, and sampling medium.

Analysis Data Coding--

Coding Performed By the Analytical Laboratories--The analytical laboratories were generally responsible for coding all analysis results for the Love Canal Study onto the Analysis Data Reporting Forms supplied by GCA Data Management, and in accordance with the instructions in the "Coding Manual for Analysis Data Reporting Forms." This involved coding analysis results for 1 to 300 pollutants per sample, using anywhere from 1 to 25 coding sheets to complete the task for a single sample.

The laboratories were expected to code and submit to GCA the results for the following types of samples:

- All field samples and field blanks sent from the Sample Bank;
- External QC samples sent from the Sample Bank;
- Internal QC samples sent from the Sample Bank for Tenax analysis;
- Duplicates of field samples created by the laboratories by running second aliquots of the samples;
- Method blanks generated by the laboratories;
- Laboratory Control Standards (LCS) and spike samples generated by the laboratories;
- Results for surrogates and internal standards added to the samples sent from the Sample Bank.

Because of these extra procedures, the coding of each air sample was a time-consuming matter. Efficient coding was further hampered by the fact that flow data sheets and met data sheets were frequently submitted very belatedly by the sampler, and individual sample data sheets were often missing. Also, because logging of air data often lagged, due to the high volume of samples processed, identification of duplicate samples was frequently difficult.

In the preceding section, we mentioned that the coding forms and manuals were updated periodically during the project, and that the fields labeled "Date to Lab" and "Analysis" were added to the Sample Data Coding Forms after coding was well underway. This particular change did not adversely affect the coding process at the Sample Bank, however, since the addition of these data to previously-coded samples was handled entirely by Data Management in Bedford. The Sample Bank sent copies of coded log book pages to Bedford, where the two new peieces of information were coded with the Sample ID for each sample. A simple computer program was then written to insert the new data into the appropriate spaces in the raw sample data records in the computer.

Over the course of the sampling program many of the coding problems eased, primarily through the efforts of the coding supervisor, who worked persistently to obtain complete and timely data from the samplers. However, initial delays created backlogs which were difficult to overcome. Measures taken to speed up the rate of coding included the hiring of the two additional coders at the Sample Bank in mid-October, and the transfer of some coding to GCA Data Management in Bedford. All the biota coding and over half the air coding were done at Bedford, using copies of log book pages and other necessary records.

By the middle of November (2 weeks after the conclusion of the sampling program), about 90 percent of all sample data had been coded. The coding of the remaining samples, many of which had been held out initially because of missing information, was completed by mid-December. Sample Data Reporting Forms were coded for a total of 8714 samples, with the breakdown by medium as follows:

| Medium | Number of Samples Coded |
|---|---|
| Air | 3090 |
| Water | 3296 |
| Soil | 1503 |
| Sediment | 353 |
| Biota | 472 |
| Total | 8714 |

QC Cross-Reference Data Coding--

Entries were made on the QC Cross-Reference Reporting Form for every set of duplicate samples collected by the Sample Bank for Quality Control purposes. It was originally expected that these sheets would be completed by

With only a few exceptions, these requirements were met. A few samples were never analyzed (because of such reasons as laboratory accidents or expiration dates exceeded), and therefore no results were submitted. Also, the Sample Bank sent some Tenax samples to the laboratories for use as calibration standards; results for some of these were reported in the standard format, while for others, no results were submitted. Results for a few external QC samples were submitted to the GCA Quality Control Officer in nonstandard format; these were coded by Data Management onto the appropriate forms.

Analysis results for the Performance Evaluation (PE) samples sent to the laboratories by the Sample Bank were to be submitted to the GCA Quality Control Officer (as well as to EPA) in EPA reporting format. Some laboratories also submitted these results on standard GCA reporting forms, although this was not required. Initially, it was planned that these samples would not be entered into the GCA data base. However, this decision was later reversed by the Project Manager, and, as a consequence, any PE results submitted by the laboratories only in EPA format were recoded by Data Management onto the appropriate Love Canal forms.

A final deviation from the standard submission process occurred in the case of the EPA Laboratory at Las Vegas. This laboratory, which was responsible for all radiation analyses, submitted results to GCA Data Management on a computer tape in GCA standard format. For these samples, the steps of keypunching and key verification were by-passed.

Laboratories identified results by Sample ID number according to the following plan:

- All samples sent from the GCA Sample Bank were coded with the Sample ID assigned by the Sample Bank.
- Duplicates created by the laboratories by running second aliquots were labeled with the GCA Sample ID number, except that the first character of that ID was changed from its initial value to "Z."
- Reports on internal standards and surrogates were coded with the Sample Bank ID number of the sample involved.
- Samples created internally by the laboratories were assinged numbers by the laboratories from a list of reserve numbers provided by GCA Data Management. A list of the numbers assigned to each laboratory is shown in Table 8.3.

Shortly after the coding forms and manuals were distributed to the laboratories in September 1980, GCA Data Management called each laboratory to see if they had any questions about coding procedures. Many questions were answered at this time, but most of the laboratories continued to contact GCA Data Management as questions arose throughout the course of the project. In addition, GCA Data Management called the laboratories if any data forms were

TABLE 8.3. RESERVE LIST OF SAMPLE ID NUMBERS FOR SAMPLES GENERATED INTERNALLY BY ANALYTICAL LABORATORIES

| Reserve numbers | Laboratory |
|---|---|
| Q00001-Q01000 | Acurex Corp. |
| Q01001-Q01500 | Battelle Columbus Labs |
| Q01501-Q02000 | Energy Resources Co. |
| Q02001-Q03000 | Compuchem/Mead |
| Q03001-Q03200 | Gulf South--Lafayette |
| Q03201-Q04300 | Gulf South--New Orleans |
| Q04301-Q04500 | (Not assigned) |
| Q04501-Q04600 | Midwest Research Institute |
| Q04601-Q06000 | PJB Laboratories |
| Q06001-Q07000 | Southwest Reserach Institute |
| Q07001-Q07500 | PEDCo Environmental |
| Q07501-Q07800 | EPA-EMSL-Cincinnati |
| Q07801-Q08000[a] | EPA-EMSL-RTP-for Tenax |
| Q08001-Q08500 | EPA-EMSL-RTP-FOR Hi-Vol |
| Q08501-Q08550[a] | EPA-ERL-Duluth |
| Q08551-Q08600[a] | EPA-HERL-RTP-for Dioxin |
| Q08601-Q09000 | Advanced Environmental Systems |
| Q09001-Q09110 | TRW, Inc. |
| Q09111-Q09149 | Wright State University |
| Q09150-Q09199 | GCA |
| Q09200-Q09500 | EPA-Corvallis |

[a]No numbers were actually used from these sets.

filled out incorrectly. These calls were made both to obtain necessary information for the samples involved and to attempt to prevent similar coding errors in subsequent submissions.

Most of the systematic coding problems were quickly cleared up, but a few lingered. A major problem was that some laboratories persisted in failing to identify the method blanks associated with samples being reported. (GCA's coding system for method blanks was poorly designed and contributed to this particular problem.) Some other problems stemmed from coders' apparent lack of familiarity with data entry requirements. More than one character might be squeezed into one box on the coding form, for example, or a decimal point might be placed on the line between two boxes. Such entries could not be keypunched. The use of subscripts, superscripts, and Greek characters was also troublesome to keypunchers. Other errors in coding presented no trouble in keypunching, but caused problems of interpretation once entered into the computer. For example, comments which ran from one line to another on the analyte form might be separated from each other when sorting of cards took place; or a comment which the coder entered on one line on a form, but which applied to all lines on the form, ended up, of course, on only one card.

GCA attempted to catch such errors through visual inspection of coding forms before the forms were sent to keypunch, and we also attempted to describe these problems, and ways of avoiding them, to the laboratory coders. A coding training session for coders from all participating laboratories would have been a valuable aid in preventing such problems.

Before laboratories submitted their coding forms to GCA, they made two copies, one of which was submitted to EPA, and one of which was retained in the laboratory files. The copies retained by the laboratory were to provide back-up if loss occurred during transit (which, fortunately, it never did), and they were to serve as a reference for the laboratories if questions arose about the data they had submitted. GCA Data Management did, in fact, call upon the laboratories to check certain file copies from time to time. This was particularly important in the few instances in which the Sample ID number was entered incorrectly on the reporting form, since in these cases the laboratory log books could not have yielded the correct information required.

The analytical laboratories sent their Analysis Reporting Forms to GCA via Federal Express for prompt and guaranteed delivery. (ERCO, situated nearby GCA, used regular mail service.) All forms were sent to the attention of GCA's Love Canal Document Control Officer, who logged them in by sender, date, package number, and general contents, before handing them over to Data Management. The Data Mangement log system for coding forms is described in a separate section below.

Coding Performed by GCA Data Management--GCA Data Management assumed responsibility for coding the following data:

- PE data submitted in EPA format only;
- Data for all samples analyzed by GCA;

- A set of results submitted by PJB Laboratories for samples extracted by New York State;
- All data submitted by the EPA Laboratories at Ada, Oklahoma, and at Corvallis, Oregon;
- TSP data for HiVol samples;
- All data from Wright State University (WSU) and Advanced Environmental Systems (AES);
- Dioxin data submitted by EPA-HERL at RTP;
- All data on the External QC Reporting Forms (Form J60, card type A0);
- Certain Comments Forms (card type A4).

We mentioned above that the laboratories were not required to submit PE data on standard Love Canal Reporting Forms. If results were submitted in nonstandard form, GCA Data Management coded them onto the appropriate Analysis Reporting Forms. Since the true values were not available to GCA for these samples, the standard reporting form used was the Analyte Concentration Form (card type A1). GCA coded these forms in accordance with the "Coding Manual for Analysis Data Reporting Forms."

Similarly, procedures in the coding manual were followed in the coding of GCA samples, the PJB/NYS-extract samples, the samples from the EPA Laboratories at Ada and Corvallis, and the TSP data for HiVol samples. GCA assumed responsibility for coding the PJB/NYS-extract data because results for these 21 samples were submitted in nonstandard form. This happened because it was not clear from the outset whether or not these samples were to be entered into the GCA data base. EPA resolved this by requesting GCA to enter these data into the GCA raw data base, but not verify them. GCA Data Management coded the samples from Ada and Corvallis as a time-saving measure. These samples were ready for coding only a few days before the March 18, 1981, deadline for data validation. Since these data had to be passed through the raw data and verified data stages before validation could take place, haste was necessary. Because the two laboratories were not acquainted with Love Canal coding procedures, it seemed expedient to perform the coding at GCA. Therefore, the results were sent to GCA in nonstandard form via Telex. TSP data for HiVol samples were coded by GCA Data Management because these data were submitted to GCA via Telex in nonstandard form after the Analysis Reporting Forms had been submitted.

GCA's reasons for coding the WSU (dioxin), AES (TOX, TOC), and EPA-HERL-RTP (dioxin) data were different. At the outset of the program we were uncertain as to the data fields which would have to be coded for the special analyses performed by these laboratories. As it happened, some extra fields were required, and when this was established, the coding manuals had already been issued. Rather than updating the analysis data coding manual to

cover these special fields, the decision was made to code the data at GCA. This decision seemed particularly reasonable from GCA's viewpoint, because very little data (only one to four pollutants) were reported for each of the samples involved.

The Analyte Concentration Form J09 (card type A1) and the Internal QC Form J26 (card type A2) were designed specifically for reporting Total Organic Carbon (TOC) and Total Organic Halide (TOX) data submitted by AES. The fields on Form J09 were no different from the fields on Analyte Forms J01-J08, but the columns were arranged differently on J09. Here it was designed so that more than one sample could be reported on each sheet, provided that the date of analysis remained constant. TOC and TOX (pollutant codes D01 and D02) were reported in g/l (ppb) as were other pollutants in water. Conductivity (pollutant code C02) was reported in ohms, and pH values (pollutant code C01) were expressed in standard form. The Internal QC Reporting Form J26 had one more field than did the other Internal QC Forms (J11-J25). This field was "% Recovery," which was used to report the percent recovery of the surrogate reported on Form J26. This was coded in columns 66-69, with the decimal point indicator falling between columns 68 and 69. More than one sample could be coded on this form, and the analysis dates did not have to remain constant.

The Analyte Concentration Form J10 (card type A1) was designed for reporting dioxin (TCDD) results as submitted by WSU and by EPA-HERL-RTP. Two more fields appeared on this form than appeared on other A1 forms (J01-J09). "Percent Recovery" of the internal standard ($^{37}Cl_4$-2,3,7,8-TCDD) was coded as a whole number, right-justified, in columns 56-58. "Minimum Detectable Concentration" was coded in parts per billion (ppb) in columns 59-63, with the decimal point indicator falling between columns 60 and 61. Concentrations of dioxin (pollutant codes D03 and D04) were also expressed in ppb. More than one sample could be reported on Form J10, provided that the analysis date remained constant.

GCA's other major coding effort was the completion of the External QC Reporting Form (card type A0) for all external QC samples. GCA assumed this responsibility since the laboratories were not provided with the true values for these samples. Coding of this form was not covered in the Analysis Data Coding Manual, but it was completed in a manner similar to the completion of the Internal QC Reporting Forms. The major difference between the two form types was that the External Form required neither the "specific method" designation nor the indicator for type of QC sample. Thus the comments field on the A0 form extended from column 57 through column 72. True values were coded in the "Expected Concentration" field. More details on GCA's coding and processing of external QC samples are provided in a later section of this report.

Finally, GCA coded Comments Forms (card type A4) in certain circumstances. First, if a laboratory submitted information about method blanks in separate lists, or over the phone, GCA Data Management coded the required A4 forms. Second, GCA sometimes added comments about the results submitted by laboratories. This was most frequent for External QC samples,

where a comment was added if the GCA Quality Control Officer felt the QC sample was inappropriate or if conversion of units was required to bring reported results into conformity with the true values. Finally, GCA coded comment cards to explain the absence of results for some samples. This was done if the sample was voided by the Sample Bank or by the analytical laboratory, or if no results were expected because the sample was a back-up duplicate whose mate had already been analyzed. These comment cards were added for two purposes: to provide information about the lack of results; and to "close" the sample from the perspective of the data handling system. (Closure was implied because once any "A" cards were attached to a sample, it was assumed that analysis results for that sample were completed. In fact, laboratories frequently submitted results in piece-meal fashion and, as a result, the closure concept was violated.)

Any forms coded by GCA Data Management were subsequently treated in the same manner as were the laboratory-coded forms. They were entered into the raw data system, and raw data reports on the samples involved were sent for verification to the laboratories which had originally submitted the results or who had custody of the sample.

## RAW DATA PROCESSING

Raw data processing for a sample was initiated by the receipt at GCA, Bedford, of Sample Data or Analysis Data Reporting Forms. Raw data processing activities included logging and inspecting the reporting forms, keypunching and key-verifying them, edit-checking the punched cards in the computer, solving any apparent problems, entering the new data into the master raw data file, and generating computer reports on the new raw data. Each of these activities is described below.

### Log System for Data Reporting Forms

All Sample Data and Analysis Data reporting forms received by GCA Data Management were individually logged in when they arrived, and their path to the computer was also tracked in the log book. The Love Canal Data Clerk was responsible for the entire log system for data form. Figure 8.3 illustrates the form which was designed for the study.

#### Rationale for the Log System--

The log procedure for data reporting forms was designed as part of the document control program for the Love Canal Study. The code numbers on the top left corner of the data forms were arranged in accordance with this document control system. In addition to the required document numbers, each form also carried a serial number which Data Management used in logging and tracing the data sheet.

Each data sheet was logged individually, because during the data preparation phase individual sheets were often separated from their original packages. The system was designed so that these separated sheets could be re-filed with their proper packages when desired, and so that the loss of individual data sheets could be detected. It was important, for example, to

LOVE CANAL
DATA REPORTING FORM LOG

| Serial Nos. | Received From Lab | | Sent to Keypuncher | | | | Rec'd from Keypunch | | Date to Computer |
|---|---|---|---|---|---|---|---|---|---|
| | Date | Package | IK | AA | Date | Batch | Date | Package | |
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COMMENTS:

Figure 8.3. Love Canal Data Reporting Form Log.

be sure that every sheet sent out for keypunching was actually returned to GCA. The system was also intended as a mechanism for tracking down individual data sheets if questions about their contents arose at any point.

As Figure 8.3 illustrates, the serial number was used as the key identifier in the log system. When the log system was designed, the advantages and disadvantages of using the serial number as the key were weighed against the advantages and disadvantages of using the Sample ID number. The Sample ID number appeared preferable for many reasons, particularly since all data in the computer system were referenced by this number. We judged, however, that logging large numbers of data sheets by serial number would prove unmanageable. We imagined that a batch of analysis results would include samples with widely varying ID numbers, each of which would have to be entered individually. On the other hand, we imagined that in a particular batch of forms, each type of form might be sequentially numbered, and therefore we could enter the serial numbers as a range. Because we were expecting to make multiple entries for approximately 50,000 data sheets over a 4-month period, the option of logging by range of numbers was judged as critical. Hence, the data reporting form log system was keyed to the serial number on the form, and, in most instances, we achieved the advantage we sought. The Sample Bank and most laboratories did send their forms in batches which were sequentially numbered by serial number.

The Log Entry System--

The data form log book was set up as a loose-leaf notebook with separate sections for the Sample Bank and for each of the EPA and subcontractor laboratories which submitted data forms to GCA. Within each laboratory's section, a separate page (or set of pages) was maintained for each type of "J-form" used (J01-J08, J10-J25, J31, J41).

When a package of forms was received, information entered into the log book for each sheet included the serial number, the date received, and the package number which had been assigned by the Love Canal Document Control Officer.

The next entry was made when the forms were sent to a keypuncher; this entry included an indication of which keypuncher (in-house or external) was selected, the date the forms were sent to the keypuncher, and the batch number of the forms shipment. (Generally the package number was used also as the batch number.) Each data sheet was individually logged by date when it was returned from the keypuncher, and the final entry was made in the log book when the cards associated with the code sheets were entered into the computer. When the data sheets had passed through the Data Management log system, they were transmitted to the Love Canal Document Control officer for filing by package number.

It should be emphasized that while we saved a great deal of time by entering ranges of numbers in the log book we were careful to make sure that every single data sheet included in that range was present at every step of the logging process. Further, for multiple-page forms, we checked to be sure that every page of each set was present at each logging step. If a sheet

which was first entered as part of a range was later separated from its package, an asterisk was placed in the "Serial No." column, and notes about this sheet were made on the reverse side of the form.

Use of the Log System--

The log book was used routinely to keep track of the Love Canal work load of the in-house and external keypunchers, so that decisions could be made on which keypuncher should receive the next packages of data. Also, the log book was reviewed regularly to make sure that batches of data had been returned from the keypunchers within a reasonable period of time. When a package had been out for a week, the data clerk contacted the keypuncher about it.

A very frequent and crucial use of the log book occurred when it was necessary to check computer reports of data against the data sheets which were submitted to GCA. From the computer report we could ascertain the date on which the data were entered to the computer, as well as the laboratory and the type of analysis performed. Using this information we could turn to the correct laboratory and "J-Form" page in the log book, and use the "Date to Computer" column to isolate the package (or packages) which could have contained the desired sample. We could then go directly to the files of data forms to look up these packages.

The log system was, of course, convenient to use when questions arose about data sheets with particular serial numbers. This type of question was most commonly raised by the originating laboratory. We were able to look up the package number associated with the serial number, and go directly to the package files to find the desired sheet.

We also learned that when we made the initial log entry, we should check to make sure that the same serial numbers had not been submitted in a previous package. Some laboratories had a habit of re-submitting some forms, either because some data sheets "belonged" with both packjages (e.g., method blanks), or because they used this as a mechanism for submitting revisions to their data. By using the log book to catch and analyze double submissions before keypunch, we saved a great deal of confusion and effort later on.

Problems with the Log System

The major problems with the data log system occurred when data sheets for a single sample were distributed through more than one package, or when Data Management processed sheets for the same sample on different dates. In either case, it became quite difficult to track down a desired data sheet. A logging (and filing) system keyed to the Sample ID Number would have alleviated this problem, but as was pointed out above, such a system was not practical.

One improvement to the actual log system could also have helped somewhat in alleviating the problems. Namely, if the serial number and/or the package number had been keypunched and entered as part of the computerized data, then tracking down data sheets would have been a much simpler matter.

## Computer Reference Files

Before discussing the details of the processing of raw data, it is appropriate to describe three reference files which were accessed by the system software during processing of sample data and analysis data. Two of these (COORDS and POLL XREF) could be updated independently of the flow of raw data, while the third (ID XREF) was generated during raw data processing. The coordinate reference file (COORDS) was used to update the planar coordinates for sample data, and the pollutant code reference file (POLL XREF) was used to check the validity of pollutant codes on analysis data and to label output reports. The ID cross-reference file (ID XREF) was used to make sure that sample data were not entered into the system more than once, that sample data were present before analysis data were present, and that each sample was verified only once.

Coordinate Reference File--

The sample data coding plan called for coders to enter planar coordinates on the S1 card for each sample coded. For ground water samples, coordinates which were accurate to a tenth of a foot were also entered on the S6 card. This system was problematic for two reasons: first, coordinates were not always available at the time of coding; and second, some coordinates were changed during the course of the study. Therefore, we created the coordinate reference file (shown as Item 2 on Figure 8.1) so that coordinates could be added to sample data that had already been entered into the raw data system. After this file was created, coders were no longer required to enter the planar coordinates on the sample data report forms.

The coordinate reference file is listed in Appendix H. The data fields in the file include:

- Stratum
- Site ID
- Easterly coordinate
- Northerly coordinate
- Well number for ground water samples <u>or</u> medium for biota samples or for soil samples taken from house sites (this field is blank for all other samples).

The medium or well number field was necessary because at some sites sampling took place at more than one location, and thus more than one set of coordinates was available. For instance, at a home site, sampling for air and water inside the house would require one set of coordinates, while soil sampling in the yard would require a different set of coordinates. For ground water, two wells were typically located on the same site, and each had its own set of coordinates.

When a file of sample data was run through the program which inserted the coordinates into the coordinate field(s), the first requirement was that the stratum and site ID on the sample card had to match the stratum and site ID of an entry in the coordinate file. Further, for ground water, coordinates were applied only if the well number of the sample matched a well number in the coordinate file. For biota samples, coordinates were applied only if the medium in the coordinate file specified "BIO". For soil samples, if a set of coordinates with the medium specified as "SOIL" were available, these were applied; otherwise, coordinates with the final field left blank were used. For air samples, sediment samples, and water samples which were not ground water, this final field was required to be blank. If the proper combination of stratum, site, and medium could not be made, no coordinates were inserted, and an error message was printed.

The coordinate file was first used after a large portion of sample data had already been entered into the system and was residing in the temporary verification (TEMPVER) file (step 13 in Figure 8.1). Therefore the entire TEMVER file was processed with the coordinates file so that all samples processed up through that date would have correct coordinates. After that, all sample data were processed through the coordinates application program at the time of data editing (step 3 in Figure 8.1).

The coordinates file was updated as necessary during the remainder of the study. Coordinates were added for new sites, and some coordinates were changed for existing sites. When coordinates were changed, this required changing the coordinates in the sample data for samples taken at these sites and already entered into the system. This was done through the sample data verification process (step 14 in Figure 8.1) if the sample had not already been verified, or it was done through the verification correction process (step 32 of Figure 8.1) if the sample had been verified.

Pollutant Code Reference File--

The pollutant code reference file was established at the outset of the study, and it was updated as needed throughout the study. It is listed in its final form in Appendix H. The file contained the following information for each pollutant identified by EPA for the study.

- Pollutant Name
- CAS Number
- Three-character ID code assigned by GCA
- Alert level concentration.

The first character of the three-character code assigned by GCA was designed to indicate the type of medium and/or pollutant involved. The characters were assigned as follows:

A - Acid portion of semivolatiles

B - Base portion of semivolatiles

C,D - Conductivity, dioxin, and other special analyses

F - Foam plugs; pesticide analyses

I - Inorganics

P - Pesticides in water, soil, sediment and biota

S,H - Surrogatês, spikes, internal standards, LCS compounds

T - Tenax ; volatile analyses

V - Volatiles in water, soil, sediment and biota.

The pollutant reference file, which is item 6 on Figure 8.1, was accessed by four computer programs in the data handling system. It was used by the analysis data edit program (ALEDIT) and the verification action data program (VERED) (steps 7 and 24 in Figure 8.1) to check that the pollutant codes entered on the analysis data and verification action report forms were valid. If pollutant codes on these forms could not be located in the POLL XREF file, the edit programs printed an error message.

The POLL XREF file was used for two purposes by the RAWSUM and by the VERFILE programs (steps 15 and 27 on Figure 8.1). When these programs were preparing the raw data listings and verified data listings, they searched the POLL XREF file for the CAS number and pollutant name of each pollutant code encountered and printed all three pieces of information on the output reports. Finally, the alert levels in the POLL XREF file were used by the RAWSUM and VERFILE programs to prepare the Alert Reports for raw and verified data. Each quantified concentration for each sample was checked against the alert level for the appropriate pollutant in the POLL XREF file. Entries were made on the alert report for each concentration exceeding the specified alert level.

ID Number Cross-Reference File--

The Sample ID Number cross-reference file (ID XREF) was built up during the course of raw data processing. Every time the RAWSUM program (Item 15 of Figure 8.1) was run, the ID numbers from all sample data entered into the raw data file since the last run of RAWSUM were merged into the ID XREF file. Included in this file were not only the Sample ID Numbers assigned by the Sample Bank, but also the sample tag number and the chain-of-custody numbers associated with each sample.

The ID XREF file was used to generate printed reports which listed all the cross-reference numbers for every sample in the raw master file. The file was also accessed by four of the computer programs used for raw data processing and data verification. The sample data edit program (SAMEDIT)

referred to the ID XREF file to make sure that sample data for a single sample were entered into the raw data system only once. The analysis data edit program (ALEDIT) checked the ID XREF file to be certain that sample data were already present for all analysis data being edited. (If sample data were not present, then processing of the analysis data had to be postponed.) The program which applied verification changes to the raw analysis data (VERAP; Item 26 on Figure 8.1) also accessed the ID XREF file, and changed the initial character of the Sample ID to a "V" to indicate that the sample had been verified. Finally, the edit program for verification action cards (VERED) referred to the ID XREF to make sure that each sample was only verified once.

## Pre-Processing of Sample and Analysis Data

Pre-processing of sample data and analysis data was comprised of a set of activities designed to make the data as complete and correct as possible before they were merged into the master raw data file. Sample data and analysis data passed through separate but parallel pre-processing paths.

### Visual Inspection and Correction--

After the data reporting forms were logged in by the data clerk they were visually inspected by the raw data staff for omissions and errors. On sample data sheets, QC samples were checked for accompanying QC comment cards (S5 card); air samples were checked for accompanying flow data and met data; all samples were checked for the presence of the stratum, site ID, sample date, and other common information. On analysis sheets, analyte forms were checked for the presence of a concentration or a results indicator, internal QC forms were checked for the presence of a QC-indicator; qualitative analysis sheets were checked for the presence of CAS numbers; and comment sheets were checked for serial numbers. A check was also made for valid codes on the data sheets; it was particularly common for lab names and analysis methods to be mis-coded, shifted, or missing.

In many instances the errors detected during this rough inspection could be corrected by GCA Data Management withouth contacting the originator of the data form. Shifted codes, mis-coded media, or missing card sequence numbers, for example, could be easily fixed by GCA. For missing fields, however, calls to the Sample Bank or the laboratories were necessary. Sheets with problems, or packages with numerous errors, were set aside until answers to questions could be obtained.

### Keypunch and Key-Verification--

Once the data sheets were cleaned up, they were returned to the data clerk for logging to keypuncher. Keypunching was done either in-house at GCA or by an external agency which was selected for the Love Canal work. Any data sheets with special instructions were routed to the in-house keypuncher so that verbal instructions could be given, and questions could readily be answered. The external keypuncher also called GCA if any questions in interpretation arose, and they flagged any data sheets which were illegible or which had obvious errors (e.g., missing Sample ID). Thus the keypunch stage itself served as a further net for error detection. Computer cards were

key-verified as well as keypunched before they were returned to Data Management. Data forms were logged in by the data clerk as the next activity in the raw data pre-processing phase.

Selection of Analysis Data for Processing--

The next step for Sample data was entry of the cards into the computer, but analysis data went through one more step before they were submitted to the computer. This step was to select for processing those analysis data for which sample data were already present in the computer. The data handling system was set up on the premise that sample data would always precede analysis data into the raw data system. This assumption was based on prompt sample data coding, and a 30-day analysis period before analysis data were submitted. In fact, the coding of sample data was very delayed in many cases, and laboratory analysis was sometimes completed quite swiftly. Therefore it was extremely common for analysis data to arrive at GCA prior to the arrival of the sample data. To prevent mismatching of sample data and analysis data it was necessary to make the manual search for acceptable analysis data. The search was quite time-consuming, since it involved checking the Sample ID cross-reference list against the analysis data reporting forms, and then pulling out the appropriate computer cards for selected samples. We tolerated this system for some time, but in December, when some sample data were still not coded and the volume of incoming analysis data ballooned, we made adjustments in the computer programs to handle the problem. When the raw data editing program was run, analysis data which could not be matched with sample data were set aside in a separate file, where they were held until the next raw data run (step 9 in Figure 8.1, "Data Flow Diagram").

Data Editing--

Analysis data selected for processing, as well as all sample data, were next submitted to the computer for processing in their respective edit programs (ALEDIT and SAMEDIT). These are shown as steps 7 and 3 in Figure 8.1. A more detailed illustration of the edit portions of the data flow system is also shown in Figure 8.4.

The edit programs checked to make sure that required information was present, and that all information present was acceptable. For example, the Sample ID and medium were mandatory on all cards, and error messages were printed if these were missing. The ID number, the medium, and many other fields were allowed only specific ranges or values, and error messages were printed if unacceptable data were present. Error messages were also printed if data fields were in conflict with one another (e.g., if a concentration was supplied on an analyte form and the "Not Detected" column was also marked). In some cases the edit programs made changes in the data. For example, the correct code for the medium "Water" was "H2O," where the final character was alphabetic. Frequently this character was keypunched as a zero. This particular error was automatically corrected by the edit program. A complete list of edits and checks made by the ALEDIT and SAMEDIT programs is given in the Appendix.

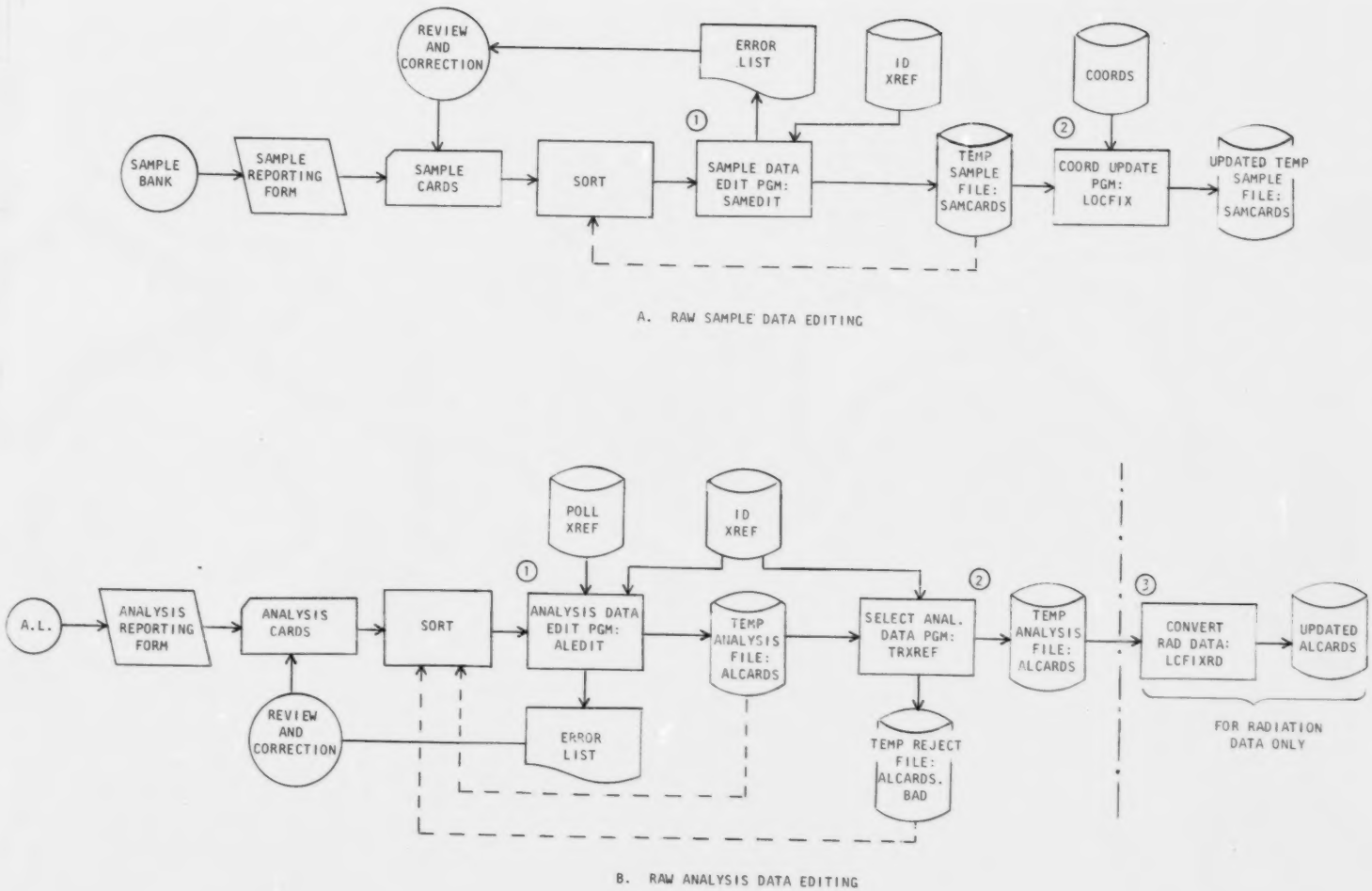


Figure 8.4. Data editing process.

The printout from each of the edit programs included:

- List of cards as submitted to the program
- List of error messages
- Cumulative summary of the number of cards of each type in the run
- Cumulative list of cards in the edit run, sorted by Sample ID, card type, and sequence number, with each card identified by line number in the temporary data file.

The raw data team examined each error message and made any changes necessary. As with the visual inspection, many errors could be fixed immediately, while others required tracking down necessary information. Frequently the data team traced back to the data reporting form to see if the error message resulted from a keypunching error. If the data had been correctly punched, then telephone calls to the data originators were necessary to resolve the problems.

Corrections were made to the data through a PANVALET update process. Correction cards were prepared on the basis of the line number of the incorrect data card in the temporary data file. When these cards were submitted to the computer, additional raw data cards could be added to the deck. When the edit program was run again the error list would be based on the new cards as well as on the cards previously entered. This cycle was repeated until all data cards were thoroughly edited.

All data cards were accumulated in temporary data files (see Figure 8.4) until the raw data manager elected to proceed to the next phase of raw data processing (usually a cycle lasted about one week). All edited sample data were accumulated in one temporary file. At the outset of the study, all edited analysis data were accumulated in one temporary file, but in a modification designed to replace manual selection of analysis data, the analysis data were later separated into two files. One of these held data for which sample data were present in the raw master file, and the other file held "rejected" analysis data, for which sample data were not present yet. The "rejects" file was reprocessed each time the ALEDIT program was run. This is illustrated in Item 2 of Figure 8.4b.

A slight exception to the usual processing pattern occurred when the EPA lab at Las Vegas submitted radiation results. In this instance data were submitted on computer tape, so that the input to the sort program was the computer tape instead of the data cards. A special editing procedure was also carried out on these data by the LCFIXRD program. This program converted all concentration measurements from the normalized form in which they were reported to the standard Love Canal reporting format.

Problems Encountered during Pre-Processing--

The major problem experienced during pre-processing of data was already described above, namely, the problem of trying to identify analysis data for which sample data were already in the system. This problem was eventually solved through additional computer programming.

An additional problem, and one for which there was no simple solution, was identified during pre-processing. This was that the laboratories frequently did not send all analysis results for a particular sample in one package. Results were often sent in different packages over a period of weeks. Sometimes we identified missing data, such as specification of a method blank. Other times, as when a second extraction was run, we had no way of knowing that the first set of results received did not present a complete set of results for a sample.

If we identified specific data as missing, and could obtain them readily over the telephone, we included them in the run. Otherwise, we let the sample go through, but made notes which we passed on to the verification team.

The staggered-results syndrome slowed down the pre-processing a little, but it caused no other difficulty at this stage. It was perfectly simple to accumulate analysis data in the raw master file over a period of time. The real difficulties with the syndrome were to come at the verification stage. For example, it was possible to verify a sample without realizing that the laboratory had not even submitted all results for that sample. The ways in which these problems were handled are fully discussed in the section on verification procedures.

Missing sample data also posed problems. Again, if information could be obtained readily, it was included in the run. Otherwise, notes were made, and data were added through sample data verification procedures. Data most commonly missing were comment cards for QC samples, and meteorological data cards for air samples. Additional sample cards could not be added through the raw data system. When a sample was first entered into the raw data system, its ID number was placed in the cross-reference list. Software was specifically designed to reject any cards with this ID in future runs, to prevent double entry of sample data. Therefore, complete cards, as well as data updates, were added through verification procedures.

## Raw Data Final Processing and Report

At intervals of about 1 week from October 1, 1980, through the end of January 1981, and at somewhat less frequent intervals during February and March, the edited raw data which had been accumulating in the temporary sample data and analysis data files were merged into the raw data master file. Reports based on this updated file were issued, and a tape of new raw data was generated for EPA. These activities are shown as steps 10 to 13, and 15 to 19 on Figure 8.1. These steps are reproduced in Figure 8.5 for convenient reference.

### Final Processing of Raw Data--

The raw data sort/merge program read as input the edited sample data and analysis data files, sorted them, and wrote a tape (Item 2 of Figure 8.5) in card-image format which contained the data from these two files. The sample data were rewritten as the first file on the tape, and the analysis data were written as the second file. Tapes were sent from GCA's Computer site at Oak

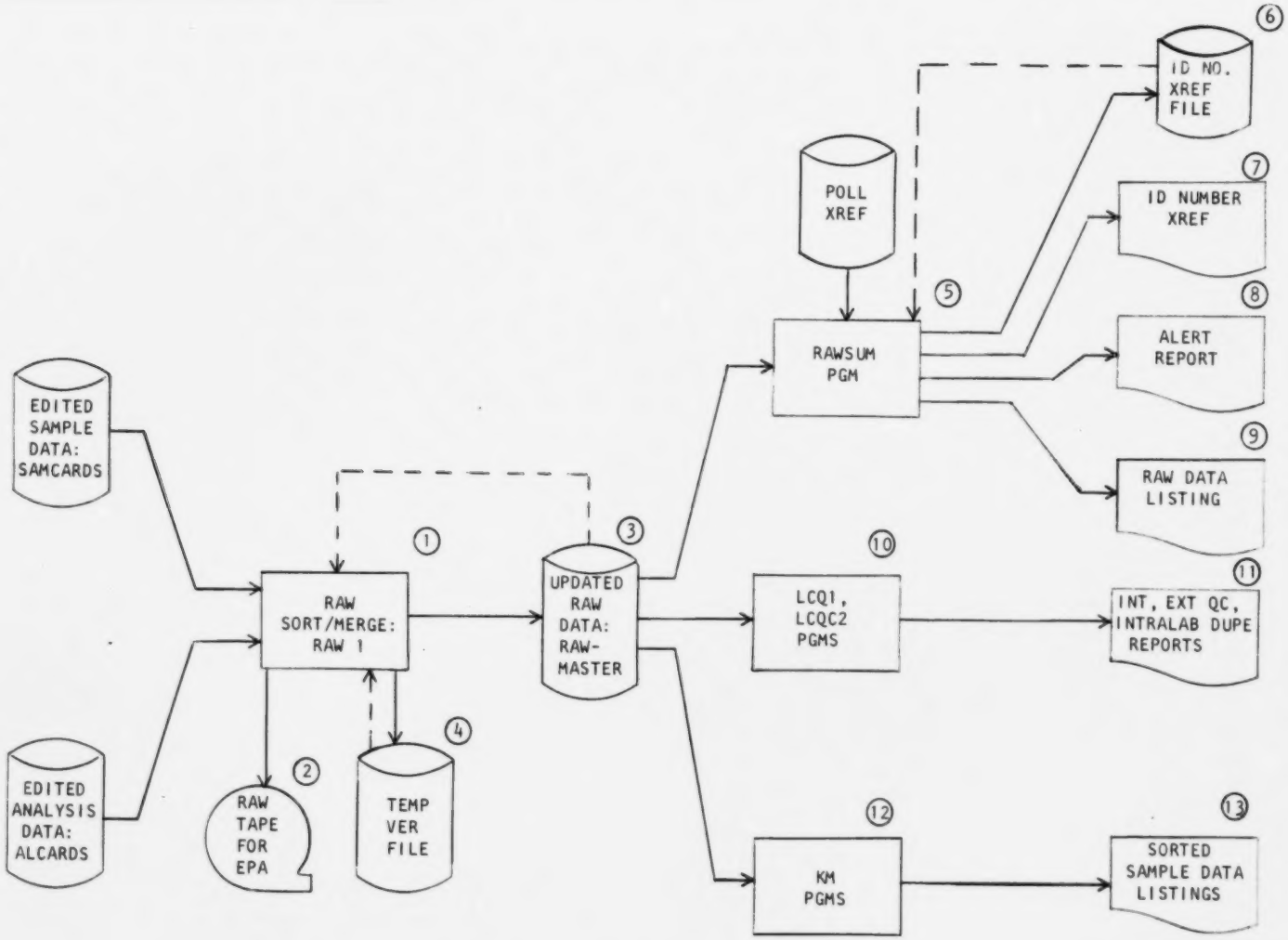


Figure 8.5. Final raw data processing flow.

Brook, Illinois, via Federal Express to EPA at RTP on the day on which they were generated. A log of these transmittals were maintained by GCA Data Management (see Figure 8.6).

The sort/merge program (RAW1) also merged all new sample data into the temporary verification file (TEMPVER; see Item 4 of Figure 8.5). Finally, the sort/merge program merged both the sample data and the analysis data into the raw data master file (Item 3 of Figure 8.5). This file was sorted by Sample ID, card type, and sequence number. The card types were sorted so that all sample cards (S1-S6) preceded all analysis cards (A0-A4) for a given sample. Table 8.4 summarizes the growth of the raw data master file over the course of the study.

Generally, the only alterations made to the raw master file were through the raw sort/merge program, which made additions to the tape, but no changes or deletions. For a period of time near the beginning of the study, however, certain fields of information were added to the sample data in the master file via a special program. The fields "date to lab" and "analysis" were added to the S3 cards in the raw master file for the first set of samples, which had been coded without this information. The S3 cards were matched with the new data fields by Sample ID number. After the decision was made to add these fields to the S3 cards, the data were coded directly onto the coding forms, and the raw master file did not have to be updated for these later samples.

Raw Data Reports--

Running of the raw sort/merge program completed the actual processing of raw data; the data next passed through the verification process. However, after each run of the raw sort/merge program, a set of report-generating programs was run, using the updated raw master file as input. Recipients of all of these reports were cautioned that the reports were based on raw data and that, therefore, some inaccuracies should be expected.

Raw Data Summary Program--The Raw Data Summary (RAWSUM) program (Item 5 in Figure 8.5) produced three reports. One of these was the cumulative ID Number Cross-Reference Report, which listed for each sample in the raw master file all the cross-reference numbers supplied on the sample cards. The report contained seven separate reports, each sorted by one of the following identification numbers:

- Sample ID
- Preparer's ID Lot
- Sample Bank to Field Chain-of-Custody Number
- QC to Sample Bank Chain-of-Custody Number
- Sample Bank to Analytical Lab Chain-of-Custody Number
- Preparer to QC Chain-of-Custody Number.

LOVE CANAL
TAPE LOG

| Tape No. | Date sent | Sent to | Contents | Date back | Use tape |
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COMMENTS:

Figure 8.6. Love Canal Tape Log.

TABLE 8.4. GROWTH OF RAW DATA MASTER FILE (IN NUMBER OF CARD-IMAGE RECORDS)

| Raw data processing date | No. records added to raw master | Cumulative size of raw master |
|---|---|---|
| 10/01/80 | 1,536 | 1,536 |
| 10/06/80 | 2,346 | 3,882 |
| 10/09/80 | 2,905 | 6,787 |
| 10/16/80 | 4,096 | 10,883 |
| 10/24/80 | 9,074 | 19,957 |
| 10/31/80 | 11,442 | 31,399 |
| 11/07/80 | 10,996 | 42,395 |
| 11/12/80 | 15,906 | 58,301 |
| 11/20/80 | 22,149 | 80,450 |
| 11/28/80 | 29,833 | 110,283 |
| 12/06/80 | 60,442 | 170,725 |
| 12/12/80 | 76,548 | 247,273 |
| 12/19/80 | 42,900 | 290,173 |
| 12/27/80 | 6,635 | 296,808 |
| 1/03/81 | 6,612 | 303,420 |
| 1/11/81 | 2,215 | 305,635 |
| 1/22/81 | 1,447 | 307,082 |
| 2/18/81 | 16,523 | 323,605 |
| 3/06/81 | 4,157 | 327,762 |
| 3/10/81 | 992 | 328,754 |
| 3/11/81 | 960 | 329,714 |
| 3/13/81 | 250 | 329,964 |
| 4/30/81 | 677 | 330,641 |

A copy of this report was sent to the Sample Bank for their use in cross-referencing samples.

RAWSUM also routed the ID Cross-Reference information to an online disk file (Item 6 in Figure 8.5) which was used for checking the ID Numbers of all raw data entered into the ALEDIT and SAMEDIT programs.

The other two reports generated by RAWSUM were based on new analysis data just merged into the raw master file. Each time the program was run, the current date was preserved by the program. Since all data in the raw master file were labeled with the date they entered the computer system, the RAWSUM program was able to compare dates and select for output only those samples added to the file since the last RAWSUM run. It should be noted here again that the system expected all analysis data for a particular sample to be submitted in one run, so that reports on an individual sample would be generated only once by RAWSUM. Analysis data for individual samples were often submitted in piece-meal fashion. RAWSUM reported these out as they were received, so sample reports were frequently incomplete.

While the RAWSUM program could not detect whether or not analysis data for a sample were complete, it did check to make sure that sample data were present for all samples for which analysis data had been added to the raw master file. As discussed above, selecting analysis data for processing was a manual operation in the early stages of the study, and sometimes analysis data were entered prematurely. We depended on RAWSUM to alert us to these slip-ups. When they occurred, we made appropriate notations by hand on the reports generated by RAWSUM.

One RAWSUM report based on new analysis data was the Alert Report, which contained an entry for every pollutant which exceeded the alert level specified in the pollutant cross-reference file. The Alert Report was transmitted to GCA and EPA for their use in identifying potential hazardous sites. The Alert Report was also used by Data Management as one aid in identifying potentially erroneous information.

The second RAWSUM report based on new analysis data was the Raw Data Listing, which was produced in two parts. The first part, which was transmitted to EPA and GCA personnel, contained most sample data (chain-of-custody information were not included), and all new analysis data, along with pollutant names and CAS numbers for each pollutant code. The second part of the report, which was separated by analytical laboratory, was sent to the appropriate labs for verification. All analysis data were present on these reports, but only a limited set of sample data were included. Information about the sample which might have biased the laboratories in their review was excluded.

Raw data listings and alert reports were sent to EPA and the subcontractor laboratories via Federal Express (an exception was nearby ERCO, for which we used regular mail). Cover letters were included with all

packages sent to subcontracting laboratories. The letter which was initially sent to all laboratories requested them to verify the accompanying data listings and to return them to GCA via Federal Express. Some laboratories declined to verify the reports; in subsequent shipments to these labs, we substituted a cover letter which acknowledged their position on verification, but urged them to check any items which GCA had flagged on the sheets. Procedures used by Data Management in reviewing and flagging all raw data listings before transmitting them to laboratories are described in the section on verification procedures.

A log of the raw data listings which were sent to laboratories (including EPA labs) for verification was maintained by the Data Management data clerk. This log is exhibited in Figure 8.7. It was maintained in loose-leaf format, with one page for each laboratory. As well as entering the processing date of the report and the date on which it was sent out from GCA, the clerk entered the number of pages in each report. This was done so that when the verified reports were returned by the laboratories, we could check to make sure that we had received the entire report. As the Figure shows, this same form was also used to log in the reports when they were received back at GCA from the laboratories. Information logged at that time included the date received and the package number assigned to it by the Love Canal Document Control Officer.

Raw Data Quality Control Programs--Two quality control programs (Item 10 of Figure 8.5) were routinely run on the raw data, and both of these included the entire file in their analysis each time they were run. One program (LCQC1) analyzed recovery rates of the laboratories' internal QC samples and of external QC samples, while the other program (LCQC2) compared analysis results for laboratory-generated duplicates and their mates.

LCQC1 presented its findings on internal QC samples in sections by medium, where the samples created internally by the laboratories (and labeled from the reserve "Q" list) were treated as a separate category. Within each category, findings were separated by type of QC sample (LCS, surrogate, or spike), and then by analysis method, laboratory, and pollutant. The results then presented for each pollutant included:

- Pollutant name and code
- Number of samples (for that pollutant, lab method, type of QC sample and medium)
- Average recovery rate (mean ratio of observed to expected concentration)
- Standard deviation of recovery rate.

If a sample were processed through more than one analysis method, or if more than one extraction of the sample was analyzed by the same method, each analysis was treated as a separate sample by the LCQC1 program. Error messages were presented by LCQC1 when revoery rates could not be calculated. This happened when expected concentrations were absent or coded as zero, or

LOVE CANAL STUDY
LOG OF RAW DATA REPORTS
SENT TO LABORATORIES

LABORATORY:

| DATE SENT | SENT VIA | | PROCESSING DATES | REPORT PAGES | DATE RECEIVED BY GCA | PACKAGE # |
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Figure 8.7. Love Canal Study log of raw data reports sent to laboratories.

when observed concentrations were absent. These error messages enabled GCA Data Management to detect errors not found by the edit programs. The most frequent cause of error messages was a coding of zero for both the observed and the expected concentrations, in instances in which the compounds were not actually used for QC purposes by the laboratories. GCA Data Management deleted the entries for these compounds from the data base during verification.

The final section of the LCQC1 report was a summary of recovery rates for external QC samples. This report was also separated into sections by medium, and within each medium the findings were presented by analysis method, laboratory, and pollutant. The same data were presented for external QC samples as for internal QC samples, and error messages were printed if recovery rates could not be calculated. (Towards the end of the study, a program was written to analyze the accuracy of external QC results through an analysis of differences. This program (QSPECA) used the validated data as input).

The LCQC2 report first printed pollutant-by-pollutant results for each laboratory-generated sample and its mate. The information printed included:

- Laboratory
- Sample ID
- Pollutant Code
- Concentration for original sample
- Concentration for duplicate aliquot (sample ID beginning with Z)
- Difference between the two concentrations.

Entries were made in the report only if a quantified (nonzero) concentration was reported for at least one member of the pair.

The second part of the LCQC2 report was a statistical analysis of these intralab duplicates, summarized for each medium by laboratory and pollutant. Information for each pollutant included:

- Laboratory
- Pollutant name and code
- Number of observations
- Mean difference between observations
- 95 percent probability limits
- Standard deviation divided by $\sqrt{2}$.

Results of the LCQC2 program were reviewed by EPA and GCA Quality Assurance staff to monitor laboratory performance while the study was ongoing. When substantial amounts of data had been verified, another program (QSPECZ) was written to analyze the validated (or verified) data in the same way LCQC2 analyzed the raw data.

Sorted Lists of Sample Data--A variety of sets of selected sample data, sorted on different fields, were generated by a set of programs called the "KM" Programs (Item 12 of Figure 8.5). These programs were written in response to requests from GCA staff (and named for the first person who made a request), who used them in a variety of ways during the study. Typically, the reports were used to monitor and review sample data, and the only information printed about analysis data was the Julian date on which they were entered into the computer (or this field was left blank if no analysis results had been received). A summary of the KM Reports and their uses is given in Table 8.5.

## Processing of External QC Samples

External QC samples were handled in a special way, since the observed values were reported by the analytical laboratories, while the true values had to be added to these data by GCA. The Sample Bank supplied Data Management with lists of QC samples and their true values. To expedite processing of QC samples as they were sent in by the laboratories, Data Management prepared External QC Reporting Forms (card type A0) ahead of time. A sheet was pre-coded with pollutant codes and true values for each of the QC samples which was due to arrive at GCA.

The next step was to identify the QC samples when they arrived at GCA, so that their observed concentration values could be coded on the A0 sheets next to the pre-coded expected concentrations. Some results were sent from the laboratories directly to GCA's Quality Control Officer. These results were copied and the copy passed on to Data Management, where the observed concentrations were coded on the A0 forms.

The remainder of the QC sample results were submitted to GCA on standard Analyte Concentration Reports Forms (card type A1), with no special identification. It was impractical to search for QC samples among incoming data sheets. Instead, we compared our list of QC samples against the reports produced after each update of the raw data master file. Thus, these QC samples were identified after they had already been entered into the raw data base. The observed concentrations were then copied from the raw data listings onto the A0 sheets with the pre-coded true values.

Whether the QC samples were coded from the raw data listings or from sheets provided by the Quality Control Officer, all A0 sheets were transmitted to the Quality Control Officer for review before they were keypunched. This step was taken to ensure that true values were correctly entered for each sample and that observed values were reported in the same units as were the true values. Procedures used during this quality control review are described in the Quality Control section of this report.

TABLE 8.5. KM REPORTS AND THEIR USES

| Report | Samples included | Sort field | Use |
|---|---|---|---|
| KM1 | All | Stratum, Site ID, Medium, Sample ID | Monitor sampling program by site |
| KM2 | All | Medium, Sample Date, Stratum, Site ID | Monitor sampling program by date |
| KM3 | All | Medium, Lab Name, Sample Date, Date to Lab | Monitor analysis load of laboratories, keep track of accounts with labs |
| KM4 | All | Medium, Sample ID | Look up information by Sample ID |
| KM5 | Ground water | Well No., Analysis | Monitor results for each well |
| KM6 | All | Sample tag | Verify sample daa |
| KM7 | Ground water | Sample ID | Look up ground water informtion by Sample ID |
| KM8 | QC (Q in Col 72, S1 Card) | Medium, Sample ID, Stratum, Site ID | Monitor receipt of external QC analysis data |

A0 sheets were returned to Data Management with the signature of the Quality Control Officer on each sheet, indicating that the review was complete. The sheets were then checked by Data Management for any changes or additions required. Frequently, the QC officer requested the addition of comments about the sample, for example. Once such adjustments had been made, the A0 sheets were submitted for keypunching. From that point on, the A0 data traveled through the raw data processing system along with other analysis data. For those QC samples which Data Management had identified through raw data listings, the end result was a set of "A0" data and a set of "A1" data, with the observed concentrations on the A0 cards being the same as the observed concentrations on the A1 cards for the corresponding pollutants. Data coded on A0 sheets appeared on the raw data listings under the heading of "External QC Results."

A total of 322 external QC samples were processed, of which 284 were one-part samples, 33 were two-part samples and five were three-part samples. For an additional 17 samples (13 one-part and 4 two-part samples) which were on the Sample Bank's list of External QC samples, no results were submitted to GCA by the analytical laboratories. Table 8.6 gives a breakdown by medium and type of analysis of the external QC samples for which results were received and processed. Table 8.7 gives a similar breakdown for samples for which analysis results were not received.

Several types of problems were associated with the processing of external QC sample results; the consequences of these problems were usually felt during the verification process. The first type of problem which occurred was that results for some samples were submitted both on standard forms to Data Management and on EPA forms to GCA's Quality Control Officer. In these cases, A0 sheets were generally coded twice, and the results entered twice into the raw data system. The verification team had the task of spotting duplicate entries and deleting one set.

The second type of problems occurred when laboratories changed the observed concentrations submitted for the QC samples. This happened several times when "TRACE" values were changed to quantified values. (This is discussed thoroughly in the Quality Control section of this report.) When changes were made before the A0 sheets were entered in the raw data master file, then the verification team still had to change the values already submitted on A1 cards. When labs made changes after the A0 cards had been submitted to the computer, the verification team had to change the values on both the A0 cards and the A1 cards.

A third problem with the processing of external QC samples stemmed from the fact that A0 and A1 cards for a sample were typically submitted to the computer on different dates. There was the constant danger that the sample would be verified before the A0 cards were submitted to the computer. This did, in fact, happen in several instances, and the A0 data had to be added through special corrections to the verified data (Step 32 on Figure 8.1).

TABLE 8.6. QC SAMPLES WITH ANALYSIS DATA

| Sample type | Air | Water | | | | Soil/sediment | | | Grand total |
|---|---|---|---|---|---|---|---|---|---|
| | | One-part | Two-part | Three-part | Water total | One-part | Two-part | Soil/sediment total | |
| TENAX | 76 | | | | | | | | 76 |
| Foam | 75 | | | | | | | | 75 |
| Hi-Vol | 6 | | | | | | | | 6 |
| RAD | | 3 | | | 3 | 5 | | 5 | 8 |
| TCDD | | | | | | 12 | | 12 | 12 |
| FL/NT | | 13 | | | 13 | | | | 13 |
| Vol | | 8 | | | 8 | 12 | | 12 | 20 |
| Vol-Purge | | 5 | | | 5 | 5 | | 5 | 10 |
| PCB | | 1 | | | 1 | 1 | | 1 | 2 |
| Pest/625 | | 13 | | | 13 | 12 | | 12 | 25 |
| Chlor Hydro | | 5 | 2 | | 7 | 3 | | 3 | 10 |
| Acid + B/N | | | 8 | | 8 | | 1 | 1 | 9 |
| Phenol + B/N | | | 5 | | 5 | | 6 | 6 | 11 |
| B/N only | | | | | | 2 | | 2 | 2 |
| Phenol only | | 2 | | | 2 | 1 | | 1 | 3 |
| ICP379, ICP476 and AA476 | | | | 5 | 5 | | | | 5 |
| AA476 and AA379 | | | 4 | | 4 | | 7 | 7 | 11 |
| AA476 only | | 8 | | | 8 | | | | 8 |

(continued)

TABLE 8.6 (continued)

| Sample type | Air | Water | | | | Soil/sediment | | | Grand total |
|---|---|---|---|---|---|---|---|---|---|
| | | One-part | Two-part | Three-part | Water total | One-part | Two-part | Soil/sediment total | |
| AA379 only | | | | | | 1 | | 1 | 1 |
| ICP379 only | | 9 | | | 9 | | | | 9 |
| ICP476 only | | 6 | | | 6 | | | | 6 |
| Total | 157 | 73 | 19 | 5 | 97 | 54 | 14 | 68 | 322 |

Total one-part samples - 284

Total two-part samples - 33

Total three-part samples -5

TABLE 8.7. QC SAMPLES WITH NO ANALYSIS DATA

| Sample type | Air | Water | | | | Soil/sediment | | | Grand total |
|---|---|---|---|---|---|---|---|---|---|
| | | One-part | Two-part | Three-part | Water total | One-part | Two-part | Soil/sediment total | |
| TENAX | 1 | | | | | | | | 1 |
| Foam | | | | | | | | | |
| Hi-Vol | | | | | | | | | |
| RAD | | 1 | | | 1 | | | | 1 |
| TCDD | | | | | | | | | |
| FL/NT | | | | | | | | | |
| Vol | | | | | | 4 | | 4 | 4 |
| Vol-Purge | | 1 | | | 1 | | | | 1 |
| PCB | | | | | | | | | |
| pest/625 | | | | | | | | | |
| Chlor Hydro | | | | | | | | | |
| Acid + B/N | | | | | | | 1 | 1 | 1 |
| Phenol + B/N | | | | | | | 1 | 1 | 1 |
| B/N only | | | | | | | | | |
| Phenol only | | 1 | | | 1 | 3 | | 3 | 4 |
| ICP379, ICP476 and AA476 | | | | | | | | | |
| AA476 and AA379 | | | 1 | | 1 | | 1 | 1 | 2 |
| AA476 | | | | | | 1 | | 1 | 2 |

(continued)

TABLE 8.7 (continued)

| Sample type | Air | Water | | | | Soil/sediment | | | Grand total |
|---|---|---|---|---|---|---|---|---|---|
| | | One-part | Two-part | Three-part | Water total | One-part | Two-part | Soil/sediment total | |
| AA379 | | | | | | 1 | | 1 | 1 |
| ICP379 | | | | | | | | | |
| ICP476 | | | | | | | | | |
| Total | 1 | 3 | 1 | 0 | 4 | 9 | 3 | 12 | 17 |

Total one-part--no results - 13

Total two-part--no results - 4

The final problem associated with the processing of the QC samples was the vulnerability of the system to human error. An automated system could have ensured that all external QC samples were identified when they were first entered into the raw data processing system, that no QC samples were verfified without the A0 data, and that the A0 data were identical to the A1 data. The manual system was instituted because external QC results were already in the computer when the QC sample list and true values were transmitted to Data Management, and the potential for difficulty was not fully appreciated at the outset.

## DATA VERIFICATION

Verification of sample data and of analysis data were handled separately, and verification of sample data was a far simpler process than that of verifying analysis data. This was true partly because the volume of sample data was much smaller than the volume of analysis data. But the verification of analysis data was also more complex because the analytical laboratories were involved in the process, whereas GCA verified all sample data internally. The two verification processes are described below.

### Verification of Sample Data

Verification of sample data appears as step 14 on Figure 8.1. The steps related to sample data verification are shown also on Figure 8.8.

The first and most critical step in sample verification was the review of the data by the Sample Bank. The "KM6" report was produced for this purpose. This report listed selected data for all samples in the raw master file, and it was sorted in order of the sample tag number. This enabled the Sample Bank to proceed systematically through their files of sample tags to verify the information on the KM6 report. The data fields which the Sample Bank verified for each tag number were:

- Sample ID
- Stratum
- Site ID
- Sample Collection Date
- QA/QC Status of Sample
- Well Number (for ground water).

Any errors which were detected were written directly on the KM6 report, and the report was transmitted back to Data Management when the review was completed.

The first such review was conducted by the Sample Bank at the end of November, and reviews were conducted on a weekly basis until the end of December, when all sample data had been entered into the raw master file.

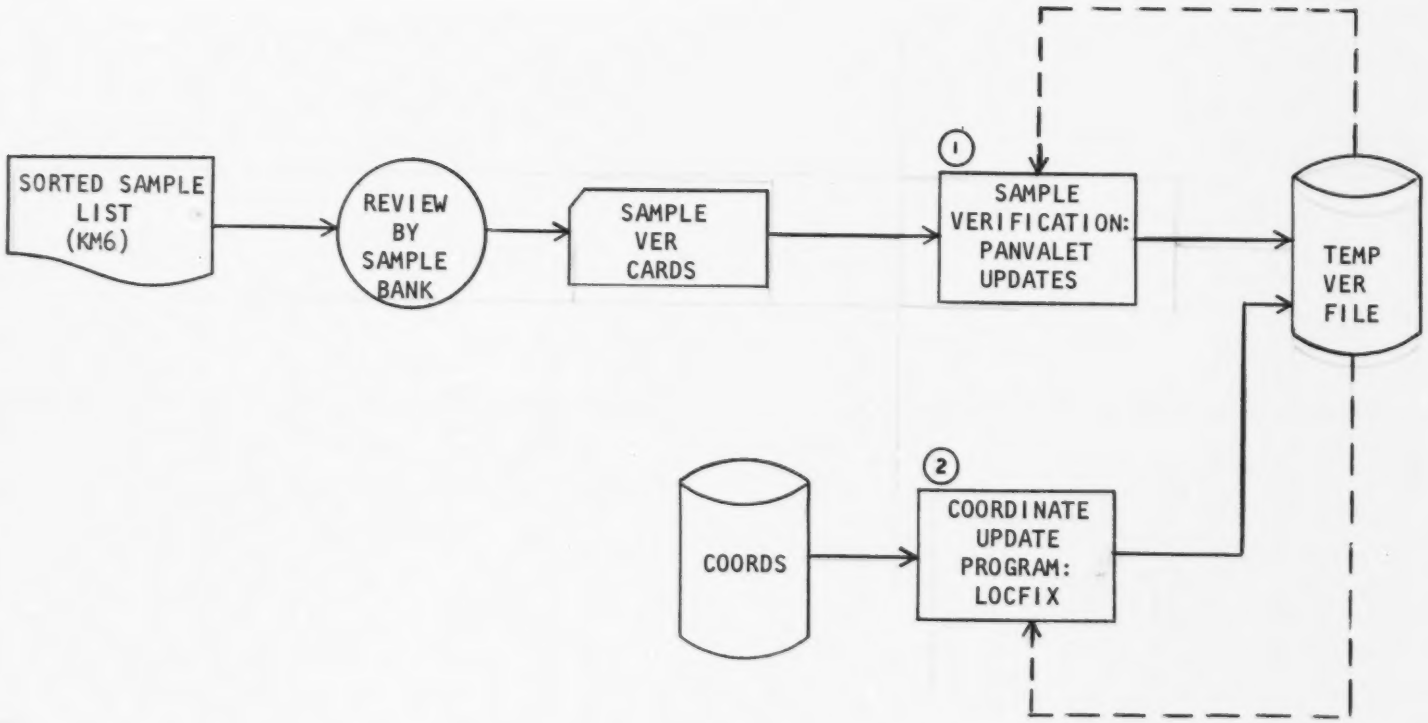


Figure 8.8. Verification of sample data.

When errors were discovered in the raw sample data, no changes were made to the raw data master file itself. Rather, changes were made to the sample data residing in the temporary verification file (TEMPVER). Data Management used the update process available in the PANVALET Ⓣ file management system to make the required changes to the TEMPVER file (see Item 1 on Figure 8.8). Changes were accomplished as follows:

- A listing of the TEMPVER file was printed on the computer.
- Errors marked on the KM6 report were transferred to the TEMPVER listing.
- PANVALET Ⓣ update cards were coded, identifying changes, additions, and deletions by line number in the TEMPVER file and by column number in the line.
- The PANVALET Ⓣ update cards were keypunched and submitted to the computer.
- A printout of the updated records was reviewed by Data Management.

This same update method was used when errors in the raw sample data were detected through means other than the formal verification review by the Sample Bank. Errors were discovered at various times by EPA and GCA staff.

A special program, rather than the PANVALET Ⓣ update process, was used on one occasion for a one-time update of coordinates for all samples in TEMPVER. This action was taken when a sizeable number of errors was discovered during verification of the coordinates, at a time when a large amount of sample data had been entered into the data system. The coordinate update procedure, which is shown as item 2 in Figure 8.8, is discussed more fully in the section above on the Coordinate Reference File.

Verified sample data were retained in TEMPVER until the corresponding analysis data had also been verified and placed in TEMPVER. The analysis data verification procedures and the ensuing creation of the verified data file are described in the following section.

## Verification of Analysis Data

Laboratory Review of Raw Data Listing Sorted by Lab--

The Raw Data Listing Sorted by Lab (hereafter referred to as Raw Data Lists) and the corresponding Alert Reports were two of the listings generated weekly by GCA Data Management in a program designed to report Love Canal sampling data to the EPA. Selected sample information and complete analysis information were listed for every sample on the Raw Data List.

The sample data printed on the Raw Data Lists included the sample ID, medium, collection date, sample time, source and analysis lab. Other types of sample information, such as coordinates, depth, and sample location (which

were printed on the Complete Raw Data Listings), were not provided on the Raw Data Lists, so as not to bias the laboratory review. Exhibit 8.1 provides an example of the sample information included in the Raw Data Lists.

All analysis data submitted to GCA by the laboratories were included in the Raw Data Lists. The Lists also included GCA's coding of true values for external QC samples, and GCA's coding of Performance Evaluation results which were submitted to the Quality Assurance Manager at GCA. In addition, the Lists included full reports on laboratories for which GCA coded all analysis data (AES, WSU, EPA at Corvallis, EPA at Ada, Oklahoma, dioxin analysis by EPA at RTP, and NYS extractions analyzed by PJB Laboratories).

On the Raw Data Lists which were generated during the first seven raw data runs of the study, the analysis method was used to identify the analysis results. When it was realized that the method did not provide a complete identification of results, the analysis date was added as a further identifier. The date of analysis was included on the Raw Data Lists beginning with the run of November 12, 1980.

The purpose of the Alert Report, in which all concentrations above a predetermined level were printed, was two-fold. First, the report was used by GCA and EPA to identify potentially hazardous sites at Love Canal. The report was also used by the GCA Data Management Group to identify outliers* in the form of unusually high concentrations which resulted from transcription or keypunch errors.

For instance, if the Alert Report identified compounds that had consistently high concentrations throughout the Raw Data List, Data Management assumed that the unusually high concentrations were specific to that group of samples and no action was taken. If a concentration were unusually high in comparison to other concentrations for that compound, then Data Management compared that concentration to the concentration on the original coded sheet. As a result of this comparison, one of two things occurred. If the concentrations differed, then the unusually high concentration was attributed to a keypunch error. The Raw Data List was corrected, and the sample ID for which there was an incorrect concentration was listed in the verification problem book** to be corrected by the GCA verification coordinator during the verification process. If the concentration on the Raw Data List was the same as that on the original code sheet, then the concentration was flagged in red on the Raw Data List. This indicated to the laboratory that they should scrutinize that sample ID. In addition to marking potential errors identified through the Alert Report, the verification coordinator flagged other potential problem data and missing data.

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*Outliers which were in the form of unusually low concentrations could not be identified through the Alert Report.

**The verification problem book was a record, listed by lab, of all samples for which there were data processing errors which were to be corrected during verification.

Page:_____

**RAW DATA LISTING**

This Report is based on raw data entered into the system between 810122 and 810218

**********

**********
**SAMPLE DATA**
**********

| Sample No.: | Medium: | Sample Date: | Time: | Source: | Analysis Lab: |
|---|---|---|---|---|---|

**********

Exhibit 8.1. Sample information on raw data listing sorted by lab.

After the Raw Data Lists were reviewed by the verification coordinator, they were logged into the Love Canal Verification Form Log (illustrated in Exhibit 8.2) by the data clerk and sent to the laboratories via Federal Express. Information recorded in the log book included the date that the raw data listing was sent out and the number of pages in the report.

The Raw Data Lists were sent out to all the labs for their review. However, not all labs reviewed or verified their Raw Data Lists. The GCA Data Manager requested, through correspondence (see Exhibit 8.3), that the verifying laboratories compare the Raw Data Lists item-by-item with the information originally used to prepare the coding sheets. If the information were correct, then a check mark was to be placed beside the entire sample. If the information were incorrect, then a line was to be drawn through the incorrect information, and the correct information was to be written on the Raw Data List.

Raw Data Lists were also sent to the laboratories that were not verifying; accompanying these lists was a request that they review any data items that had been marked in red ink (see Exhibit 8.4). The laboratories were also urged to indicate any additional corrections to the data on the Raw Data Lists. Gulf South Research Institute at Lafayette was the only nonverifying lab that responded to this request.

The following list specifies the subcontractor laboratories which performed analysis on Love Canal Samples; laboratories which did not verify their Raw Data Lists are marked with an asterisk:

- Acurex Corporation
- Advanced Environmental Systems
- Battelle Columbus Laboratories*
- Compuchem/Mead Technology Laboratories*
- Energy Resources Company, Inc.
- Gulf South Research Institute at Lafayette
- Gulf South Research Institute at New Orleans*
- ITT Research Institute
- Midwest Research Institute*
- PEDCo Environmental, Inc.*
- PJB Laboratories

VERIFIED DATA FORM LOG

| Date Sent Out | Pages | Date Revd. | Pkg. No. | Date To Coder | Comment |
|---|---|---|---|---|---|
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Exhibit 8.2. Page from Love Canal verification form log.

GCA

GCA CORPORATION
**Technology Division**
213 Burlington Road
Bedford, Massachusetts 01730
(617) 275-5444
Telex 923339

TO: ANALYTICAL LABORATORIES

The Quality Assurance Program for the Love Canal Monitoring Program requires active verification of all information by the originating party. For analytical data, this involves review of a raw data report of all results submitted by the analytical laboratory. The goal of this task is assurance that the data in the system accurately reflect the results of the laboratory analysis.

The procedure to be used in verifying results is to compare the raw data report item-by-item with the information originally used to prepare the coding sheets. If all information is correct, then place a check mark (✓) next to the entire sample. Draw a line through incorrect information and write the corrected value on the raw data report.

GCA will make notations in the form of written comments or arrows pointing to certain observations. These values should be more diligently checked as they appear to be anomolous. Air samples will be reviewed by checking the column marked "REPORTED CONC".

This information has already been edited and verified several times; however, each laboratory is ultimately responsible for the accuracy of results which they have provided. To maintain the tight time schedule required by EPA, please return the verified raw data report to Diana Timlin at GCA using Federal Express within 48 hours of receipt of the data.

Mary C. Havelock

Mary C. Havelock

Exhibit 8.3. Letter to verifying laboratories.

GCA

GCA CORPORATION
**Technology Division**
213 Burlington Road
Bedford, Massachusetts 01730
(617) 275-5444
Telex 923339

I am enclosing a report on the raw data from your laboratory which we most recently processed for the Love Canal Study. I understand that you feel verification of these data is beyond the scope of your contract with GCA. Nevertheless, you may want to review this and subsequent raw data reports for your own information, and we would appreciate your reviewing any data items that we have marked in red ink.

If you should want to make any changes in the data you have submitted to GCA, please indicate these changes on the raw data reports. Please return the reports to Diana Timlin at GCA as soon as possible, even if you do not wish to make any changes, so that we may complete the verification process for these samples.

Sincerely,

Mary C. Havelock

Mary C. Havelock

MCH/dlt

Exhibit 8.4. Letter to non-verifying laboratories.

- Southwest Research Institute
- TRW, Inc.
- Wright State University/Brehm Labs

Five EPA Laboratories performed analyses on Love Canal samples:

- EMSC/EPA Cincinnati, Ohio
- EPA/Corvallis, Oregon
- EPA/Ada, Oklahoma
- EPA/EMSL/RTP
- EPA/HERL/RTP

All these EPA laboratories verified their analysis results either in writing or by telephone. (The labs at Ada, Oklahoma, and at Corvallis, Oregon, verified their results by telephone at the end of the verification process.)

GCA Data Management requested all the laboratories to return their Raw Data Lists via Federal Express within 48 hours of receipt of the data. The verifying laboratories which did not return their Raw Data Lists within 1 week were contacted by telephone to determine when the Lists would be returned. To expedite the verification process during the period of heaviest volume of verification (the week of January 4-11, 1981, when 8244 samples were verified), some of the Raw Data Lists were verified by telephone and later returned to GCA via Federal Express.

GCA Review of Raw Data Lists--

The verifying laboratories returned the Raw Data Lists to the Document Control Officer at GCA via Federal Express. At GCA, the Document Control Officer assigned package numbers to each raw data listing, as well as to all other incoming documents related to the Love Canal Project. These packages were logged into the Love Canal Incoming Log prior to their distribution to the Data Management data clerk.

Before routing a package to the Verification Coordinator, the Data Clerk first used the Love Canal Verification Form Log (see Exhibit 8.2) to record the package number, the date the package was received, and the date it was given to the Verification Coordinator. The Verification Coordinator, referred to as the "coder" in the Love Canal Verification Form Log, then logged the package number onto the appropriate page (designated by laboratory) in the Love Canal Study Log of Raw Data Verification (refer to Exhibit 8.5).

After the log-in process, the Raw Data Lists that had been verified by the laboratories were reviewed by the Verification Coordinator and her assistants. Changes, additions and deletions indicated by the verifying laboratories were coded by the verification team onto the appropriate

LOVE CANAL STUDY LOG
OF RAW DATA REPORT
VERIFICATION

LABORATORY:

| PKG. NO. | CODER* | DATA CODED | DATA KEYPUNCHED | TO DATA PROCESSING | COMMENTS |
|---|---|---|---|---|---|
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*Name provided when many people working on same lab.

Exhibit 8.5. Log sheet used by Verification Coordinator during raw data list review.

Verification Action Forms. In addition to reviewing the raw data lists for corrections indicated by the verifying laboratories, the verification team reviewed the raw data lists for accuracy and completeness. If the raw data lists appeared complete, and no additional problems were identified, the coded verification forms were logged into the Love Canal Log of Raw Data Verification (see Exhibit 8.5) and routed to kepunch. Problem samples, which were not resolved until after the major verification effort in mid-January, were listed on the front of the Raw Data Lists.

After being returned to the verification coordinator, the coded verification forms, along with their keypunched cards and their corresponding Raw Data Lists, were logged into the Love Canal Study Log of Raw Data Verification as having been keypunched and key-verified.

The review of Raw Data Lists from laboratories that were not verifying was similar to the review of Raw Data Lists from labs that were verifying, except for two differences. First, laboratories that were not verifying did not always return their Raw Data Lists. In these cases, the GCA copy of the Raw Data List was reviewed. This list was logged into the Love Canal Study Log of Raw Data Report Verification by the Verification Coordinator, as was done with Raw Data Lists verified by labs. In cases in which nonverifying laboratories did return their Raw Data Lists, these lists were entered into the verification log books and used for the verification review.

The second difference between review of verified data listings and the review of unverified data listings was that unverified listings were scrutinized particularly carefully to ensure accuracy and completeness. This procedure turned up many questions and problems, and telephone calls were made more frequently to the nonverifying laboratories than to the verifying laboratories. Otherwise, the unverified data listings were treated similarly to the verified data listings in terms of coding and computer processing.

While more problems were identified on unverified Raw Data Lists than on verified Raw Data Lists during the verification review, the types of problems encountered among each group were similar. The problems identified included:

- Missing information, such as method blanks*, CAS numbers (on A3 cards), analysis card ID block information; and expected concentrations for internal QC information;
- Incorrect labeling of internal QC information and analyte results;
- Incorrect sample ID numbers;
- Incomplete data for samples;
- Duplicate data for samples.

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*EPA laboratories were not required to submit method blanks with each sample, whereas the subcontractor laboratories were required to do so.

Identifying and correcting these types of problems required particular vigilance on the part of the verification team. A further set of problems required systematic editing by GCA, some of which was done manually, and some of which was done by computer programs. Finally, a special editing problem occurred as a result of GCA's having provided two ambiguous method codes: all samples coded with methods 625DW and 625BC had to be changed.

For all of the problems except those of ambiguous method codes, the unavailable CAS numbers, and the specific problems that were corrected through editing, solutions were sought by referring to the original coded sheets (J-forms), KM4 Report, Sample Bank Log Books, and other summary listings prepared by Data Management. If these references failed to help solve the problem, the laboratory was telephoned. The laboratories submitted the information to GCA either by telephone or by sending the information via Federal Express. The corrections were coded on verification forms and processed in the fashion described above.

The problem involving method codes 625DW and 625BC was handled in a special way. Three labs, PJB/Jacobs Engineering Group, Inc., Gulf South Research Institute at Baton Rouge, and Acurex Corporation, were affected by the method code problem. The 625DW method code problems encountered by PJB and Gulf South Research Institute were corrected by the VERED Program during verification data processing. This will be discussed at length in the section entitled Data Processing of Verified Data.

The verification team identified the problematic method code 625BC as it was used by Acurex, and corrected it during the verification coding stage. For this lab, method code 625BC was changed to 625BS when code 625CS was already used for that sample, and to 625CS when it was not already used for that sample.

A related problem occurred for data analyzed by Southwest Research Institute using the 625 method. In this case the problem was not that SWRI was using an invalid method code, but that it was using a valid method code, 625BS, improperly. Method Code 625BS was being used for samples having double listings for acid and base neutural fractions. When this occurred, the verification team combined the double-listed acid fraction and double-listed base neutral fraction, and changed the method code from 625BC to 625CS.

Missing CAS numbers were another problem that was given special attention by GCA. With assistance from GCA's laboratory personnel, a search was made to identify CAS numbers for compounds for which the numbers had not been provided by the laboratories. In most cases this lengthy search proved successful. In other cases no CAS numbers could be identified, usually because a specific isomer of the compound had not been identified by the laboratory. In these cases the verification team entered an abbreviation of the compound name in the CAS number field, or, if this was impractical, they assigned a special number to the compound and entered this number in the CAS field. This number

(typically the Sample ID number with a hyphenated numerical suffix)* was then referenced and explained in a comment card which the verification team added to the sample. In this way, compounds were reported which did not have NBS assigned CAS numbers. The CAS Number problem was treated similarly for both the verified and unverified data.

As mentioned above, specific problems were identified during the verification program which required simple editing. That is, the problem and its solution were known and the problem was corrected either by making a deletion or by combining two concentrations, or both. The specific problems included inappropriate reporting of acid and base neutral extractions by Southwest Research Institute, Gulf South Research Institute, and Acurex Corporation; inappropriate reporting of pollutant code H01 (hexafluorobenzene) by Battelle Columbus Laboratories; coding of pollutant code V13 (this pollutant was eliminated by EPA after its initial inclusion in the study); and the reporting of "0" for expected concentrations in the Internal QC Reports.

The first edit was made to semivolatile samples analyzed by Gulf South Research Institute, Acurex Corporation and Southwest Research Institute. These labs analyzed the samples by extracting both the acid and base neutral fraction for method codes 625BW or 625BS. In doing so, Gulf South Research Institute and Acurex Corporation reported both the acid and base neutural fraction results for each pollutant in the Internal QC Report analyzed by method 625BW. Southwest Research Institute reported the acid and base neutral fraction results for all compounds on the Analyte Concentration Form as well as for those on the Internal QC Report, for all samples analyzed by method 625BS.

The inappropriate reporting of semivolatile analysis data was rectified by the verification team during the review of the Raw Data Lists. The Acurex samples analyzed by method 625BW were corrected by creating a new card which combined the observed concentrations of the acid and base neutral fractions, while keeping the expected concentrations the same (i.e., the expected concentrations were not combined). The cards representing the individual acid and base neutral fractions were deleted.

The editing for Gulf South Research Institute was different from the editing for Acurex. The Gulf South Research Institute Internal QC Report included pollutant codes S32-S37. Pollutant codes S32, S33 and S34 were combined in the same manner that the Acurex samples were combined. However, pollutant codes S35, S36 and S37, which represented internal standards specifically designated as acid or base neutral fractions, were not combined. That is, the fractions were analyzed separately and the internal standards were added to each fraction individually. Therefore, they were listed separately.

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*For instance, W21073-001, W21073-002, W21073-003, etc.

As mentioned above, Southwest Research Institute listed the acid and base neutral fractions separately on the Analyte Concentration Form and on the Internal QC Report. The Internal QC Report data were corrected similarly to those of Acurex. That is, the observed concentrations were combined and the expected concentrations remained the same. The cards representing the original acid and base neutral fractions were deleted. Analyte Concentration Reports were corrected in a different manner. The correct way of reporting analyte concentration data was to list the acid fraction analysis data for pollutant codes A0-A14, and the base neutral fraction results for pollutant codes B1-B54 and B56. Instead of reporting the analysis data in this way, Southwest Research Institute reported both the acid and base neutral fractions for each pollutant. To rectify this situation, the acid fractions for pollutant codes B1-B54 and B56 and the base neutral fraction for pollutant codes for A01-A14 were deleted. The verification team determined the correct fractions for each pollutant code by referring to the original code sheets.

Simple deletions were another type of editing performed during the verification program. For instance, the verification team deleted reports on pollutant code V13. This pollutant, known as 1,2-dichloroethene, had two isomers, cis-1,2-dichloroethene and trans-1,2-dichloroethene, which were being reported as V07 and V09. The reporting of V13 constituted a duplication and consequently V13 was deemed invalid. (Unfortunately, some samples were verified before this duplication was realized. Therefore, the verified data base includes some samples for which pollutant code V13 was not deleted.)

Pollutant code H01 constituted another simple deletion. Battelle Columbus Laboratories reported hexafluorobenzene, or pollutant code H01, as an area count rather than as a concentration for all samples. While their reporting method was a valid method, it was not the method eventually chosen for the Love Canal Study. As a result of this decision, midway through the project, all of Battelle Columbus Laboratories' reports of the H01 compound were deleted from the data base.

Finally, the verification team was instructed to delete, from the internal QC data, every pollutant that had a "0" for an expected concentration. This task was performed because only the pollutants that had an expected concentration greater than "0" were actually used as internal QC compounds.

There were three groups of data which were not necessarily problematic, but which were handled differently from other data during the verification process. The three groups were GCA samples, Tenax internal QC samples, and external QC samples. The GCA Raw Data Lists were verified by Data Management by comparing the sample and analysis data to the GCA laboratory records. Corrections and processing were then handled in the standard manner.

The majority of Tenax internal QC information was coded by the laboratories. In a few instances, however, the laboratories supplied only the observed concentrations, and in these cases the verification team supplied the

expected concentrations. These true values* were coded from a list provided by Research Triangle Institute both to GCA and to the two laboratories that were participating in the Tenax analysis: PEDCo Environmental, Inc. and Battelle Columbus Laboratories.

The review of Tenax internal QC samples during verification was different from the norm. During GCA verification review, every true value for each sample designated as a Tenax internal QC sample was compared to the list provided by Research Triangle Institute. If incorrect true values appeared, they were corrected by using the verification action form and then processed similarly to the other samples.

The other group of QC samples that were handled differently during verification were the external QC check samples. In this case, each external QC sample was reviewed by the verification team to make certain that the true values had been coded, that the observed concentrations on the external QC cards (A0) matched the observed concentrations for the same pollutants on the analyte concentration cards (A1), and that external QC information was not present in duplicate. These measures were necessary because of the way the external QC data were submitted to GCA and handled during the raw data processing.

As was described earlier, some external QC data were submitted on standard reporting forms, some were submitted in nonstandard format, and some were submitted in both forms, causing duplicate (but not necessarily identical) data. If two sets of data were submitted, one set had to be deleted during verification data processing. When there were discrepancies between the two data sets, the correct set was identified by consulting with GCA's QC Officer, by contacting the laboratory, or both.

Other problems arose when laboratories submitted revised measurements for the external QC samples. In these instances, the data submitted on analyte concentration forms (A1), as well as the data coded on the external QC reporting forms (A0), had to be corrected. If the sample had not been submitted to raw data processing, then the corrections were made at this point. If the samples were in the raw data file but had not been verified, then the correction was made during the verification process. If the sample had been verified, then the corrections were made at a later date. Whichever was the case, handling of the external QC data tended to be cumbersome.

Verification Coding--

As mentioned in the section of this report on Love Canal Coding Forms, the format of the Verification Action Forms was similar to that of the Analysis Data Reporting Forms. Table 8.8 gives further information about the Verification Action Forms. Copies of each form can be found in Appendix F.

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*The true values were referred to as the expected concentrations on the coding sheets.

TABLE 8.8. DESCRIPTION OF LOVE CANAL VERIFICATION ACTION FORMS

| J form no. | Title or description | Actions allowed[a] | Card type[b] | Required information[c] |
|---|---|---|---|---|
| J51 | Analyte Concentration | A,D,C | V1 | Sample ID; poll. code if a field in columns 37-71 is to be altered or if the ID block[d] for a specific pollutant is to be altered; poll. code, concentration or "not detected" or "trace" or "qualitative" must be provided when adding a poll. code. |
| J52 | Internal QC Report | A,D,C | V2 | Sample ID; poll. code if a field in columns 37-71 is to be altered or if the ID block for a specific pollutant is to be altered; poll. code, observed and expected concentrations, as well as the identifying QC information must be provided for an addition. |
| J53 | Qualitative Analysis | A,D,C | V3 | Sample ID; CAS Number if a field in columns 51-71 is to be altered or if the ID block for a specific CAS number is to be altered; CAS number, judgment score and match score must be provided for an addition. |
| J54 | Comments | A,D | V4 | Sample ID; comments must be provided for an addition. |
| J55 | External QC Information | A,D,C | V0 | Sample ID; poll. code if a field in columns 37-71 is being altered or if the ID block for a specific pollutant is being altered; poll. code, observed and expected concentrations must be provided for additions. |
| - | General Purpose 80-Column[e] | V | V | Sample ID. |

[a]Allowable actions were A for add, D for delete, or C for change. The action was listed in column 72 of the Verification Action Form.

[b]The card type was listed in columns 72 and 78.

[c]Sequence numbers were required for all adds, but were not used for changes or deletes. Action Code and Card Type were required on all forms.

[d]Colums 1-32 represented the ID block.

[e]The General Purpose 80-Column forms were used to verify the samples that appeared to be complete and accurate in the raw data base.

The Verification Action Form used by the Verification Team to make corrections was dependent upon the type of data that was being corrected. The Verification Data Action Forms corresponded directly to the analysis cards so as to facilitate any additions, deletions or changes that may have been necessary to attain the goal of data accuracy and completeness.

The sample ID number, which could not be changed during verification, was the only piece of information from the ID block (columns 1 through 32 of each "A" card) that was necessary to code when corrections were being made to the analysis data. The VERAP1 Program, which will be discussed in the section of the report entitled Data Processing of Verified Data, copied the ID block information from the analysis data already present in the system. This facilitated the verification coding process.

An addition or change to the ID block was achieved by listing the sample ID, the change or addition (action code C or A), a V in column 76 and nothing in column 77. That is, a change or addition to the medium, method, Lab ID, date, time or sample size of the analysis data for an entire sample was achieved by using the format shown in Exhibit 8.6.

As is seen from looking at Exhibit 8.6, an altered J51, 52, 54 or 55 Verification Action form was used to code the additions and changes made to the analysis card ID block. Since this occurred for only a small proportion of samples, a special form was not created. By not specifying the card type number found in column 77, global changes or additions were applied to all of the analysis cards for the sample. For instance, the medium in the first example in the figure was missing for all the analysis data. The above format was utilized to correct the situation. The Action was "C" for "change" instead of "A" for "add" because a field was being changed; the entire line was not being added. In example two, an incorrect Lab ID was being changed to the correct one. It is necessary to note that the method, date, time and sample size for samples with more than one method were not changed or added as an ID Block correction unless the change or addition applied to all the methods. One or more additions or changes to the ID Block were allowed. Deletions were not possible as ID Block corrections.

A change action code was used on J51, 52, 53 and 55 forms when information was being added to an existing line (or card) or when a field on that line was being changed. In the frist case, the sample ID, pollutant code, new data and action code "C" were coded on the Verification Action Form. The latter case entailed the coding of the sample ID, pollutant code or CAS Number, the new data, and action code "C". The only way to change the comment cards was through the use of action codes "D" for "delete" and "A" for "add". That is, if a change was necessary, all existing comment cards had to be deleted, and then all comments appropriate for the sample were added.

A "D" for "delete" was used when an entire line was to be removed. The coding requirements for deletions were sample ID, pollutant code or CAS number, and action code.

LC 1-619-026 — J51 52, 54, 55

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 — COLUMNS 33-91 ARE IRRELEVANT FOR THE TASKS BEING DISCUSSED — 72 73 74 75 76 77 78 79 80

| | SAMPLE ID | MEDIUM | METHOD | LAB. ID | DATE MO. DA. | TIME HR. MN. | SAMPLE SIZE | ACTION | JUL. DATE | CARD TYPE | SEQ. NO. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| EXAMPLE 1 | W2 1 3 7 2 | H 2 0 | | | | | | C | | V | |
| EXAMPLE 2 | W2 0 0 3 6 | | | P J B L | | | | C | | V | |
| | | | | | | | | | | V | |
| | | | | | | | | | | V | |
| | | | | | | | | | | V | |
| | | | | | | | | | | V | |
| | | | | | | | | | | V | |

Exhibit 8.6. Change or addition to analysis in block.

The action "A" for "add" was used when a new line was to be entered. The requirements for additions included the coding of the sample ID, pollutant code or CAS number, action code, and specific fields on forms J51, 52, 53 and 55. On the J51 forms, either the concentration field had to be coded, or one of the three fields, "not detected", "trace", or "qualitative" had to be checked. On the J52 form, the observed and expected concentrations, as well as one of the internal QC descriptions, had to be coded. The judgment and match scores on the J53 form had to be coded. It was necessary to code the observed and expected concentrations on the J55 form. If these fields were not coded, the VERED program (to be discussed in the following sections) would identify and flag those samples as being inaccurate.

Analysis data were added to a sample during verification only when other analysis data for that sample had been entered into the raw data base through the raw data process. That is, no type of analysis data could be added to the system during verification unless other analysis data for that sample were already present in the system. If no analysis data had been entered into the raw data base through raw data processing, the sample was deleted from the verification process until the data were processed through the raw data system.

Verification Data Processing--

Verification computer processing was the next step after verification review and keypunch. This process was scheduled to start at the beginning of November when the review of Raw Data Lists began. However, due to unforeseen circumstances, the verification data process began on December 20, 1980, when the first verified data tape was sent to EPA. However, most of the samples were verified by mid-January. Table 8.9 presents a complete timetable of verification data processing.

The delay in verification data processing from the beginning of November to December 20 was due primarily to the laboratories' submitting incomplete analysis information to Data Management. For instance, Analyte Report Forms were frequently submitted without the corresponding method blank and/or Internal QC Report. A more ambiguous data flow problem occurred when the results of analyses by different methods were submitted by the laboratories to GCA on different dates. Data Management had no mechanism for determining which samples would receive multiple shipments of results. The lag time between the receipt of the first pieces of data for a sample and receipt of the data that would make the sample complete was up to 6 weeks. Therefore, the verification data process was delayed until it appeared that most of the samples in the data base were complete. Any samples which appeared to be incomplete were held out from verification computer processing until they appeared complete.

The keypunched verification cards and Raw Data Lists for samples which appeared to be complete were submitted to the Verification Processor for computer processing. Before being routed to the Verification Processor,

TABLE 8.9. TIMETABLE OF VERIFICATION DATA PROCESSING

| Date of verification | No. of samples verified | Cumulative No. of samples verified |
|---|---|---|
| 12-20-80 | 772 | |
| 12-27-80 | 775 | 1,547 |
| 1-2-81 | 1,054 | 2,601 |
| 1-8-81 | 1,577 | 4,178 |
| 1-9-81 | 859 | 5,037 |
| 1-10-81 | 672 | 5,709 |
| 1-11-81 | 1,080 | 6,789 |
| 1-12-81 | 715 | 7,504 |
| 1-14-81 | 191 | 7,695 |
| 1-15-81 | 240 | 7,935 |
| 1-19-81 | 70 | 8,005 |
| 1-21-81 | 67 | 8,072 |
| 1-23-81 | 172 | 8,244 |
| 1-29-81 | 141 | 8,385 |
| 2-9-81 | 429 | 8,814 |
| 2-25-81 | 494 | 9,308 |
| 3-11-81 | 547 | 9,855 |
| 3-11-81 | 73 | 9,928 |
| 3-16-81 | 161 | 10,089 |

though, the Raw Data Lists and corresponding verification forms and cards were checked against the problem book* and were then logged into the Love Canal Study General Log of Data Processing of Verified Samples (see Exhibit 8.7). A batch number (starting with 1 and ending with 49) was assigned to every group of Raw Data Lists forwarded to the Verification Processor. The Verification Coordinator recorded the groups of Raw Data Lists from batch 1 to batch 25. The batches after batch 25 were small and consisted of individual samples that had been problematic samples identified during data processing. The Verification Processor recorded the batch numbers, but did not record the individual problem sample ID's.

Once the Raw Data Lists were logged in by the Verification Processor, the verification computer processing began. The verification process was a series of computer programs designed to apply any changes, deletions or additions identified during the verification review and to generate verified data lists which were the updated versions of the sample and analysis information. A corresponding Alert Report was also printed and a tape of verified data was generated for EPA. In addition, a cumulative file of all processed verified data was created for GCA. Four major computer programs, VERED, VERAP1, VERAP2, and VERFILE were used to accomplish this task. Figure 8.9 shows in detail the portion of Figure 8.1 which pertains to the verification of analysis data and the generation of verified data files and reports.

The first step in verification computer processing was to run the verification action cards through the VERED program. VERED was a three-part program designed to edit the cards. The first part of the program listed the actions being performed. The second section reviewed these actions, performed editing on the cards, and printed error messages if any problems were identified. The third section of the program generated a print-out of the card images.

The VERED program checked the verification action cards for the validity and presence of various parameters. This program flagged invalid or missing parameters. Table 8.10 summarizes the parameters chedked by the VERED program. Editing was another task performed by the VERED program. Invalid pollutant codes, B55 and B57 through B62, were deleted. A complete list of checks and edits performed by the VERED program is provided in Appendix D-4.

The verification processor reviewed the VERED printout and compared the verification action forms to the card image section. If any errors were identified, new cards were keypunched and all the cards were run through the program again, repeating the process of review and editing. This process was repeated as many times as necessary to make the cards correct. If the cards appeared to be correct, the VERAP1 program was run.

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*The verification problem book contained notes on all samples for which any corrections were necessary. If the corrections were easily accomplished, then the corrections were completed and the sample was submitted to verification data processing through the appropriate channels.

LOVE CANAL STUDY GENERAL
LOG OF DATA PROCESSING
OF VERIFIED SAMPLES

| LABORATORY NAME | PACKAGE NUMBER | BATCH NUMBER | TAPE | COMMENTS |
|---|---|---|---|---|
| | | | | |
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Exhibit 8.7. Verification data processing log kept by Verification Coordinator.

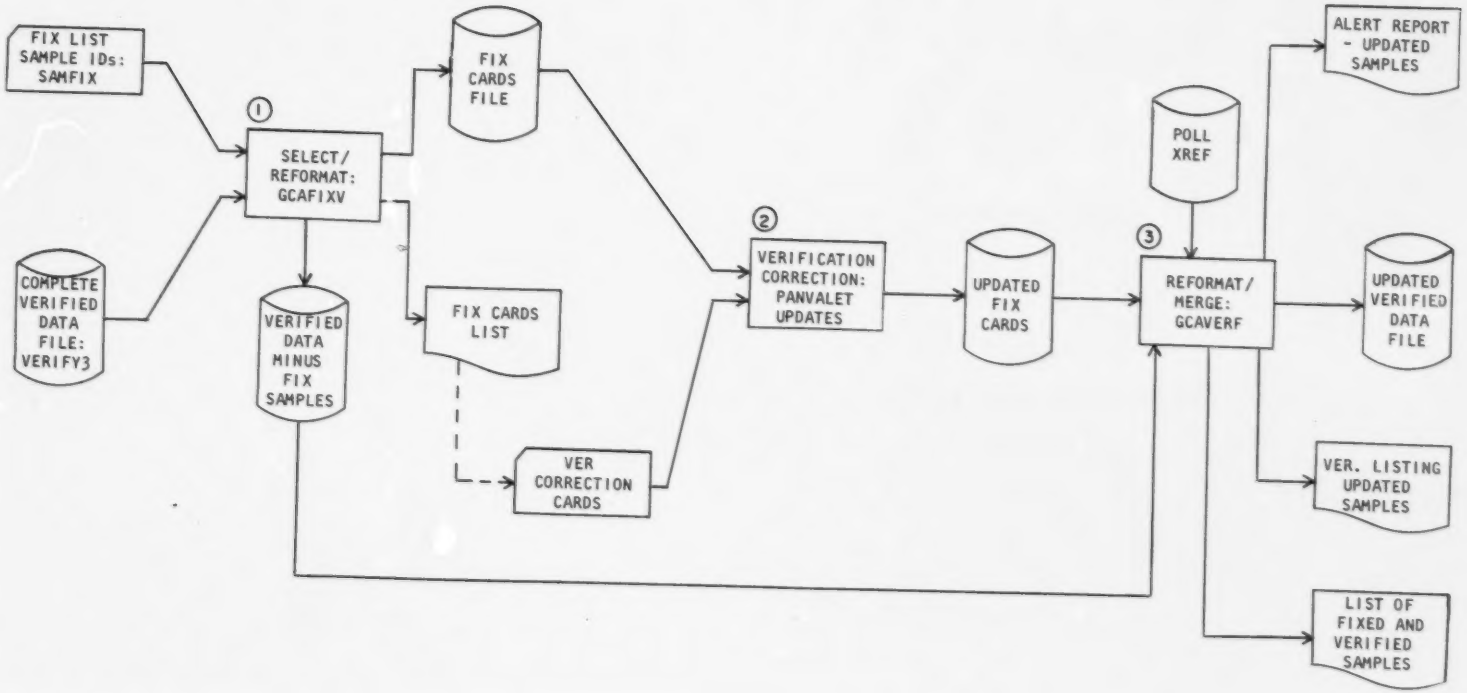


Figure 8.9. Verification of analysis data and generation of verified files.

TABLE 8.10. PARAMETERS OF VERED PROGRAM REVIEW

| | Verification action forms | | | | |
|---|---|---|---|---|---|
| | J51 | J52 | J53 | J54 | J55 |
| **Presence and Validity of Parameters:** | | | | | |
| Sample ID number | X | X | X | X | X |
| Medium | X | X | X | X | X |
| Method codes | X | X | X | X | X |
| Laboratory ID | X | X | X | X | X |
| Action command | X | X | X | X | X |
| Card type | X | X | X | X | X |
| Pollutant code | X | X | | | X |
| **Presence of Parameters:** | | | | | |
| Concentration or not detected/trace/qual. | X | | | | |
| Observed concentration | | X | | | X |
| Expected concentration | | X | | | X |
| Type of QC sample | | X | | | |
| CAS Number | | | X | | |
| Match score | | | X | | |
| Judgment | | | X | | |

The VERAP1 program searched through the master raw data file for the analysis cards of samples being verified. Without changing the raw file, it copied these data into a temporary file named "LASTVER." It then applied to this data any changes, deletions, or additions specified on the verification action forms. The VERAP1 program also did some editing; the problem of method code 625DW, mentioned in the previous section, was solved by this program, as shown in Table 8.11.

TABLE 8.11. CONVERSION OF METHOD CODE 625DW

| | Fields as coded | | Fields changed to: | |
|---|---|---|---|---|
| Laboratory | Method | Column 1 (sample ID prefix) | Method | Column 1 (sample ID prefix) |
| PJB | 625DW | W | 625BW | W |
| PJB | 625DW | Z | 625CW | W |
| PJB | 625DW | Q | 625CW | Q |
| GSLA | 625DW | ANY | 625CW | No change |

Finally, the VERAP1 program generated a printout that listed all samples in the run and printed out the analysis data for those samples having changes, deletions and/or additions made to them, or whose raw analysis data were processed on different Julian Dates. The verification processor reviewed these samples for completeness and accuracy.

Any problems identified while running the VERED and VERAP1 programs were solved by referring to the Raw Data Lists or by using the references utilized by the Verification Coordinator. Once the information needed to solve the problem was acquired, a LASTVER printout was generated and corrections were applied using the PANVALET update process. These corrections were keypunched and run through a PANVALET update program which applied the corrections to the LASTVER file. The problem samples that were not resolved were deleted from LASTVER and were processed at a later date.

When all the samples appeared to be correct, the VERAP2 program was run. The VERAP2 program closed the run by merging the analysis data that was located in LASTVER into the TEMPVER file, where the verified sample data were located.

VERAP2 generated a short printout, which was reviewed by the Verification Processor to ensure that the merging action was satisfactorily completed.

The last program run in the verification processing sequence was the VERFILE program. This program selected from the TEMPVER file the following samples:

- Samples with Sample Bank ID numbers for which sample data and analysis data were both present;
- Analysis data for laboratory-generated internal QC samples (Sample ID beginning with Q0);
- Analysis data for duplicate samples generated by the laboratories. (Sample IDs beginning with Z).

(These data were deleted from TEMPVER, leaving in TEMPVER only verified sample data for which analysis data had not yet been verified).

In its next step, the VERFILE program converted all selected data to a basic format of one record per sample.* It then merged these data into a cumulative disk file of all verified samples, which was maintained on the GCA computer. The same selected data were also written to a tape for EPA in a basic format of two records per sample.** The formats of the GCA and EPA verified data are shown in Table 8.12. A log of verified data tapes sent to EPA was maintined in the notebook which also housed the log of raw data tapes sent to EPA.

Finally, the VERFILE program generated verified data listings and an Alert Report, which were similar to the reports generated during Raw Data Processing. It also produced a Delinquency Report which listed samples for which sample data had resided in TEMPVER for over 30 days and for which no analysis results had as yet been verified.

After the verification process was completed and a tape was made, the Raw Data Lists and coded verification forms were returned to the Verification Coordinator, who filed them by laboratory in Raw Data List folders. The Raw Data Lists which had problem lists attached to them were not filed in the Raw Data List folder until the problem samples were resolved. The verification forms for miscellaneous problem samples were filed in a separate folder.

When the verification process terminated on March 17, there were only six samples remaining which still could not be verified because of unresolved problems. These were all Compuchem Mead samples for which method blanks were never submitted. On instruction from EPA, another group of samples were not

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*For samples with more than 81 cards (including sample data and analysis data), additional verified records were formed.

**The first record contained sample data, and the second record contained analysis data for samples with more than 81 analysis cards, additional verified records were formed.

TABLE 8.12. FORMAT OF VERIFIED DATA RECORDS

| Data fields | Column in verified record |
|---|---|
| A. GCA's Disk File | |
| 1. Sample ID and Medium | 1-10 |
| 2. No. of sample cards (NSAM) | 11-12 |
| 3. No. of analysis cards (NAL) | 13-15 |
| 4. Date verified | 16-18 |
| 5. Continuation character[a] (blank if only one record for sample, "A" if first record of multi-record sample, "B" if second record of multi-record sample, etc. | 19 |
| 6. Sample data (Columns 11-72, 76-77 from each sample card) | 19 through PTS; where PTS = 19 + 64 x NSAM |
| 7. Analysis data | |
| a. Sample ID, lab, time, size | (PTS + 1) through PTA, where PTA = PTS + 12 |
| b. Repeating data: cols. 33-72, 76-77, 11-15, and 21-24 from each analysis card | (PTA + 1) through (51 x NAL + PTA) |
| B. EPA's Tape File | |
| 1. Sample ID and Medium | 1-10 |
| 2. Number of data records (N) | 11-13 |
| 3. Verification date | 14-16 |
| 4. Continuation character[a] (Always "S" for Sample Data, "A" for first analysis data record, "B" for second analysis data record, etc.) | 17 |
| 5. Outfield: 64 characters - columns 11-72, 76-77 from each sample card or analysis card | 18 through (17 + 64 x N) |

[a]A maximum of 81 raw data cards (sample or analysis) were included in a single verified data record.

verified; these were samples which were extracted by New York State and analyzed by PJB Laboratories. Table 8.13 lists all samples for which analysis data were received but which were not verified.

On the whole, verification data processing went extremely smoothly. There were, however, two problems which required changes in computer programs. These included the failure to provide for more than one date of analysis (this occurred in the first three verification runs) and a problem which occurred during the first VERFILE run, when analysis cards for laboratory-generated duplicate samples were matched with sample cards. (These sample cards should have been matched with analysis results for the original samples.)

When the VERFILE program was originally designed and coded, the programmer understood that only one date of analysis would be associated with each sample. Thus, when the VERFILE program restructured the record for a sample, it saved the analysis date only from the first analysis card it encountered. In fact, a different date of analysis was possible for different methods and for each pollutant measured in the sample. After the first verification run, EPA identified this problem, and the program was immediately corrected. In addition, the following steps were taken to "fix" the data already verified.

- A list of samples which had already been verified and which had more than one date of analysis in the Raw Master File was generated.

- For the samples so identified, a data file was constructed from the Raw Master File which contained dates of analysis for each measured pollutant. This file was transmitted to EPA for correction of the erroneous verified data on their tape.

- A correction program was written by Data Management which read the correction file (described above) and GCA's verfified data file, and which applied the corrections to produce an updated verified data file.

The other problem which arose during verification action processing concerned the mismatching of sample cards with duplicate "Z" analysis cards passing through the VERFILE program. When the VERFILE program was coded, an assumption was made that the duplicate "Z" samples would not be verified before their mates. When this assumption turned out to be untrue, the result was that the analysis cards for the "Z" samples were matched with the sample cards for the original sample. In consequence, no sample cards remained to be matched with the analysis results for the original sample.

Only about 30 samples were processed in the first verification run, but some of these did happen to be duplicate "Z" samples which were mismatched with sample cards which did not belong to them. The data processed in this run were corrected as required and a change was made in the VERFILE program to prevent reoccurrences of this event. The new version of the VERFILE program

TABLE 8.13. SAMPLES NOT VERIFIED

| Sample ID | Reason not verified |
|---|---|
| Q05500-Q05506 | NYS extraction; PJB analysis. |
| Z21817 | Compuchem: No method blank provided. |
| S40619 | Compuchem: No method blank provided. |
| S45088 | Compuchem: No method blank provided. |
| Z45214 | Compuchem: No method blank provided. |
| S45509-S45510 | NYS extraction, PJB analysis. |
| S45514-S45515 | NYS extraction, PJB analysis. |
| S45523-S45524 | NYS extraction, PJB analysis. |
| S45528-S45529 | NYS extraction, PJB analysis. |
| Z45529 | NYS extraction, PJB analysis. |
| S45538-S45539 | NYS extraction, PJB analysis. |
| S45543 | NYS extraction, PJB analysis. |
| Z45543 | NYS extraction, PJB analysis. |
| S45544 | NYS extraction, PJB analysis. |
| S45547-S45548 | NYS extraction, PJB analysis. |
| S50348-S50349 | Compuchem: No method blank provided. |

checked to ensure that sample and analysis cards matched perfectly. Also, the amended program assumed that the duplicate "Z" analysis cards did not require sample cards and therefore did not match them with any.

Finally the verification team had to be alert to the timing of verification of certain samples analyzed by PJB Laboratories. As previously mentioned, PJB Laboratories had used the ambiguous method code 625DW. For some parts of the analysis report, the first character of the sample ID was changed from "W" to "Z" when this method was used, while the "W" retained for other parts of the report for this same sample. The VERAP1 program was rewritten to correct this situation by changing the method code and the Sample ID as appropriate (see Table 8.11). This meant that all PJB water samples having duplicate "Z" samples had to be verified in the same VERFILE run as the original "W" samples in case the change and merging had to be performed.

The following duplicate "Z" samples were merged with the original sample (as described above):

- Z20062
- Z20069
- Z20070
- Z20074
- Z20075
- Z20076
- Z20111
- Z20174
- Z20177
- Z20181
- Z20194
- Z20387
- Z20408
- Z20410
- Z20411
- Z20680
- Z20853
- Z20954

## Corrections to Verified Data

Unfortunately, not all samples which were processed through the verification programs were totally correct, and an additional set of procedures had to be developed to make corrections to the verified data. Some isolated errors were discovered by EPA during their review of the data (for example, the mislabeling of the type of internal QC data), and some errors were discovered which applied to several samples (e.g., the miscoding of the sampling data for air sample collection extending over a 2-day period). GCA identified several QC samples which had been verified without their true values (the data supplied to GCA on A0 cards), and some laboratories submitted revisions to some of their QC results. However, the majority of changes in verified data were made on the TOX data submitted by Advanced Environmental Systems (AES), and to the Hi-Vol analyses submitted by EPA-EMSL, at RTP. The changes to the TOX data were necessary because AES had made a systematic error

in calculating these results; thus over 240 AES samples required changes. Corrections to the Hi-Vol data involved additions, rather than changes. In this case, results for arsenic and chromium, which were measured by the lengthy neutron activation method, were submitted to GCA after the Hi-Vol samples has been verified in January. Consequently, about 220 Hi-Vol samples had to pass through the verification correction procedures.

Two types of procedures were used in making corrections to the verified data base. In a few instances "global" changes were made; for example, for all sediment samples whose source was originally coded as "RIVER," the source was changed to "STRM" (in response to a request by EPA). Such changes were made by a simple computer program which tested each sample in the entire data base and which made the desired corrections when the specified conditions were met.

Most corrections, however, were made to specific samples, which were identified by Sample ID Number. This verification correction process is shown as step 32 on Figure 8.1, and it is illustrated in more detail in Figure 8.10. Once a group of verified samples had been identified as needing corrections, their Sample ID numbers were punched on cards. These cards, along with the verified data file, served as input to a program (item 1 of Figure 8.10) which searched the verified data file for the required samples, reformatted them into card-image records, and wrote them onto a temporary disk file of "FIXCARDS." Using a listing of the FIXCARDS file, Data Management prepared PANVALET updates (item 2 in Figure 8.10) in a manner similar to the process used in updatng the TEMPVER file. The records in the updated FIXCARDS file were then reformatted to the verified record format and merged back into the verified data file (item 3 in Figure 8.10.).

Data listings and alert reports for the updated samples, in the same format as those produced by the VERFILE program, were also generated during this final step in the correction process. Table 8.14 shows the dates on which the verification correction process took place, and the number of samples processed on each date.

Because the data which were undergoing the verification correction process had already been submitted to EPA as verified data, it was important to keep EPA informed of the changes being made. The complete sample listings and alert reports produced during the process were sent to the same EPA personnel who had received the original verified data listings. Also, written lists of corrections (with details on precise changes by field and column number) were sent to the EPA Data Processing group, so that they could update their computerized data base. (EPA chose this update method in preference to receiving tapes of updated samples from GCA.) Corrections made to verified data were, of course, included in the tapes of validated data which were sent to EPA. Each time GCA submitted a tape of validated data to EPA, this tape contained all verification corrections performed through that date.

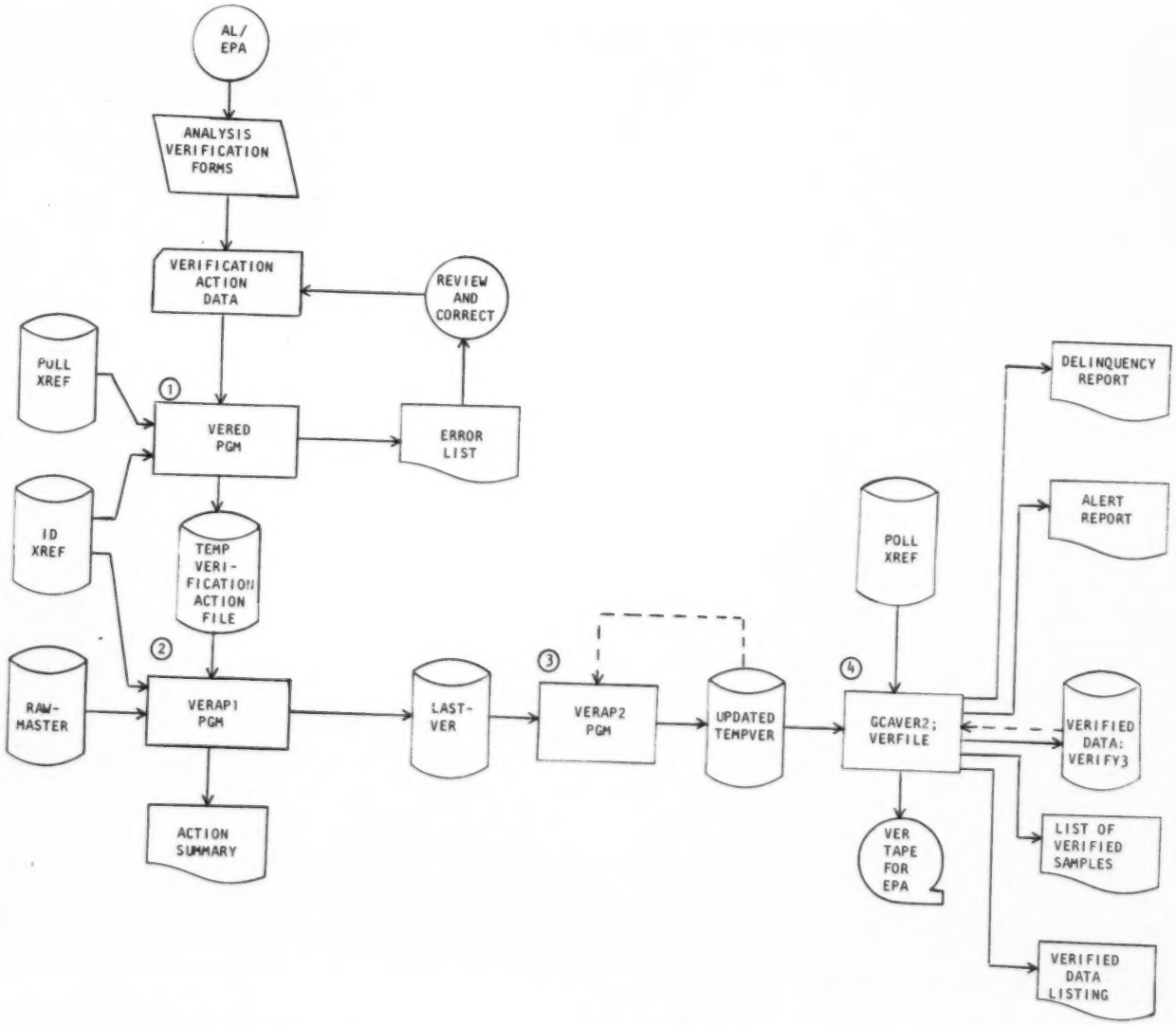


Figure 8.10. Verification correction process.

TABLE 8.14. SCHEDULE OF VERIFICATION CORRECTIONS

| Date | No. of samples | Cumulative No. of samples |
|---|---|---|
| 2/11/81 | 211 | 211 |
| 3/03/81 | 344 | 555 |
| 3/10/81 | 291 | 846 |
| 3/16/81 | 22 | 868 |
| 3/16/81 | 15 | 883 |
| 6/02/81 | 182 | 1065 |
| 11/03/81 | 17 | 1082 |

## DATA VALIDATION

### Invalidation Instructions

EPA was responsible for identifying invalid data in the Love Canal verified data base, and for providing invalidation instructions to GCA. These instructions took the form of lists of samples to be invalidated, or lists of criteria for invalidating data. Invalidations by the following sets of criteria were included in the instructions:

- Sample ID
- Lab
- Well number
- Lab name, date, method
- Medium, method, compound
- Sample ID, compound
- Lab name, date, source, compound
- Medium, compound
- Medium, compound, concentration.

When any of the first three sets of criteria above were given, the entire sample was to be invalidated. For the other sets of criteria, only the specified compounds, or the compounds associated with specific methods, were to be invalidated.

Validation Data Processing

Validation was conducted by GCA at four points in the study: on January 13, 1981; on March 17, 1981; on June 2, 1981; and on November 3, 1981. The first three dates were specified by EPA to meet their schedule requirements, while the fourth validation was performed when all validation instructions had been submitted. In January, GCA assumed responsibility only for invalidation of total samples by Sample ID number, while EPA was responsible for applying the remaining invalidation instructions. In later validations, GCA was responsible for applying all invalidation instructions.

The steps involved in GCA's January validation effort were very simple, as shown in Figure 8.11. The Sample ID numbers of samples to be invalidated were punched on cards; these cards, along with the updated verified data file, served as input to the validation program. This program simply searched the input file for the invalid samples, and passed all samples except these to the output files. The validated tape generated for EPA by this program was in the same format as the EPA verified data tape, while the GCA validated disk file was in the same format as GCA's verified data file.

The validations conducted by GCA in March, June, and November were more complicated, with the first step being to interpret EPA's invalidation instructions. When the entire sample was to be deleted (by Sample ID, by lab, or by well number), the instructions were clear and specific. However, for the remaining criteria, the Project Manager and the Quality Control Officer made some interpretations of the EPA instructions. In accordance with these interpretations, GCA proceded as follows:

- For invalidations by lab, date, source, and compound; and by lab, date, and method: invalidations were applied to field samples, to field blanks, and to the internal QC information supplied under the original sample ID, but not to PE samples, QC samples, or internal QO samples (with QO ID numbers).

- For invalidation by sample ID and compound: invalidations were applied to the internal QC information supplied under the original Sample ID.

- For invalidation by medium and compound: invalidations were applied to all pollutant codes associated with that compound, and to all samples of the specified medium, including PEs, QCs, and "QOs".

For invalidations by lab name, date and method, and by lab name, date, source and compound, GCA identified all sample ID's to be involved in the invalidation by using listings of verified samples sorted by laboratory and

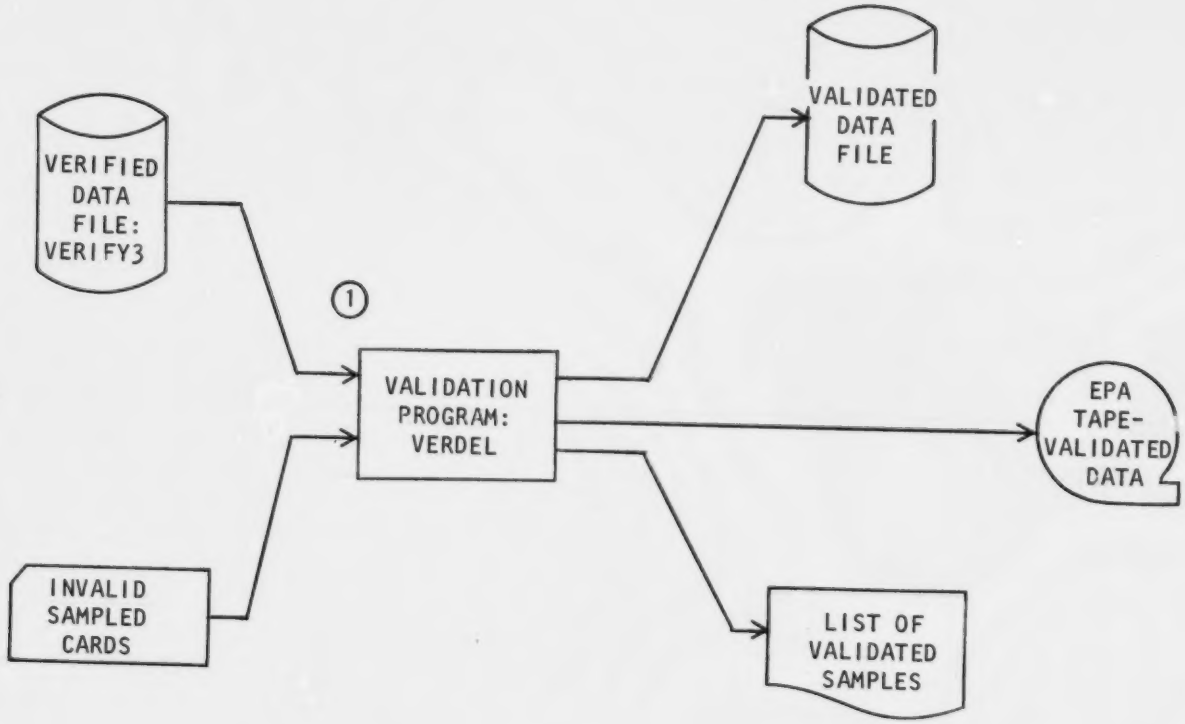


Figure 8.11. First validation: January 13, 1981.

date. Decks of cards listing Sample ID numbers of partially invalid samples and of wholly invalid samples were prepared, and invalidation activities proceded through three stages, as diagrammed in Figure 8.12.

The complete file of verified data served as input to the first stage, which handled invalidations by compound and medium. Conditions for invalidation were specified in the program "Valid1" (Item 1 of Figure 8.12). This program simply searched through the verified data file and withheld all specified combinations of compound and medium from the data which it passed on to a temporary validation file (Valid1). It should be noted that the verified data file was not altered during validation.

The temporary validation file produced by the first validation stage served as input to the second stage, in which partial invalidations by Sample ID were handled. The procedures used in this second stage of validation were exactly like those employed earlier in correcting the verified data base. That is, selected samples were reformatted into card-image records (Item 2 of Figure 8.12), and PANVALET updates were used to delete the card-image records of invalid compounds (Item 3 of Figure 8.12). Updated samples were reformatted to the verified format (Item 4 of Figure 8.12) and were merged with the remaining verified records into a second temporary validation file (VALID.FINAL1).

In the final validation stage, the samples which were being wholly invalidated were handled. The procedure used here was the same as the invalidation procedure used in January for this same purpose, except that in this case the input data file was the temporary validated data file generated by the second validation stage (VALID.FINAL1).

Corrections to Validated Data

As happened with the verified data, so it happened with the validated data that some errors were detected after the validated data tape had been generated for EPA in March. Exactly the same procedures were followed in correcting the validated data as were followed in correcting the verified data. That is, PANVALET updates were applied to the samples involved, which had been written in a separate file in card-image format. The updated cards were then re-formatted and merged with the remaining validated data. A new tape of validated data was produced for EPA at this time. The validation correction procedures took place in June and in November, at the time of the validation runs. (Identical corrections were made to these same samples in the verified data base.)

QA/QC PROGRAMS

Earlier, in the section which described reports based on the raw data file, we discussed two programs (LCQC1 and LCQC2) which generated some QC information. LCQC1 generated reports on recovery rates of internal and external QC samples, while LCQC2 compared analysis results for the two aliquots of laboratory-generated duplicate samples. In the present section we describe a set of programs which generated QC reports based on the validated (or verified) data file.

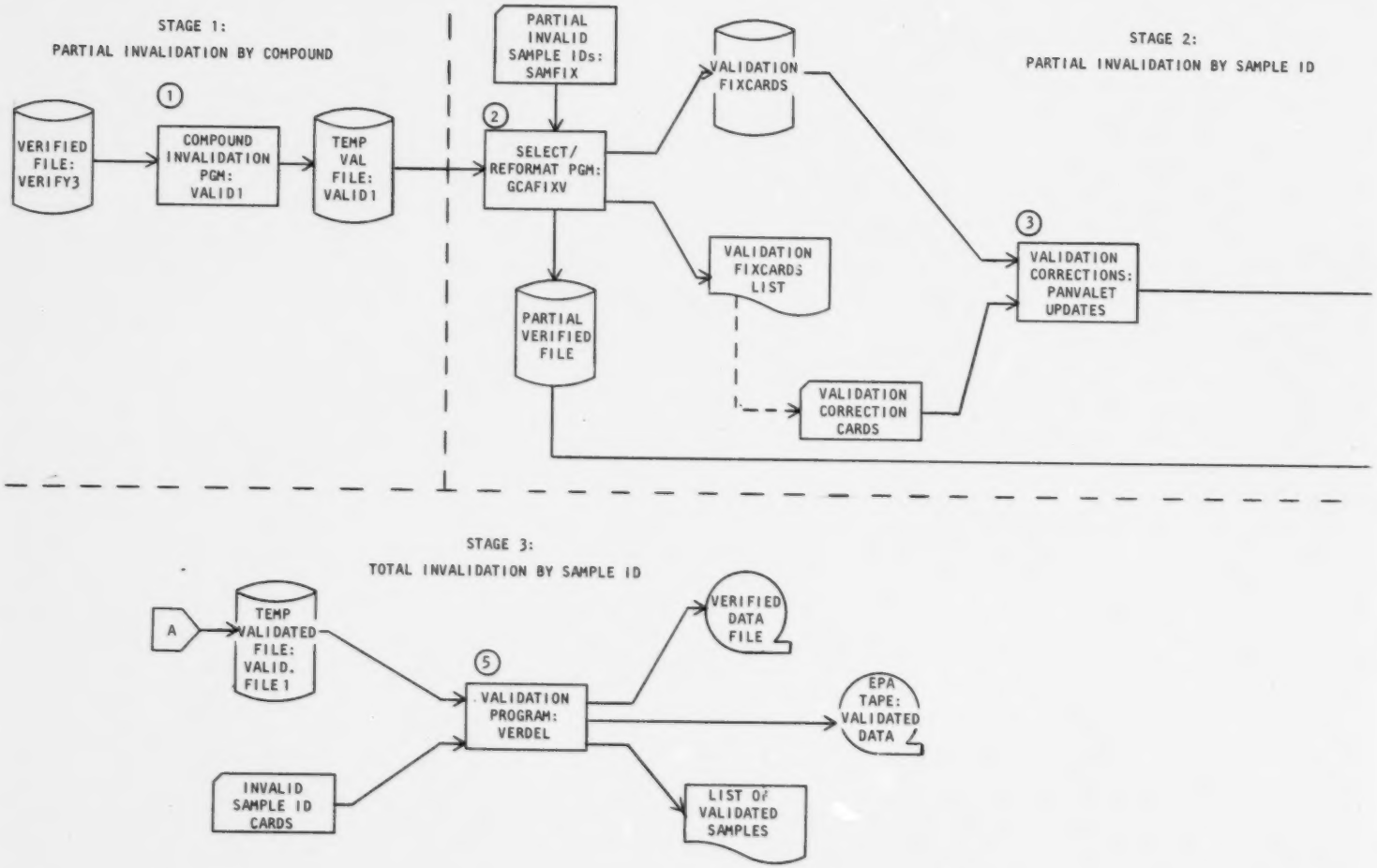


Figure 8.12. Validation process for March, June, and November 1981.

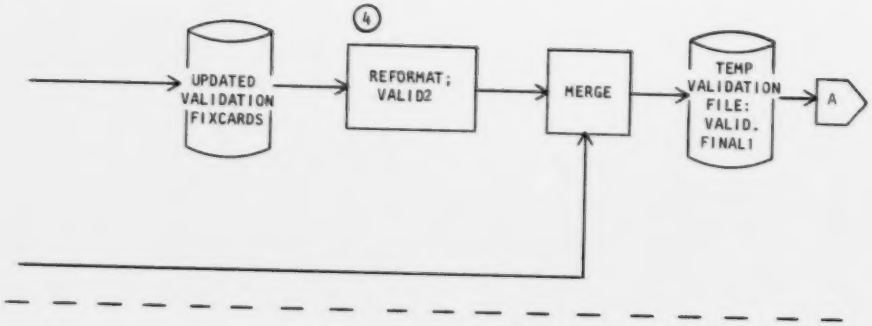


Figure 8.12 (continued)

The QA/QC programs which generated reports based on the validated data file are grouped together as step 38 of Figure 8.12. In fact, several separate QA/QC programs were designed, as summarized in Table 8.15.

TABLE 8.15. QA/QC PROGRAMS RUN ON VALIDATED DATA

| Program | Purpose | Analysis performed |
|---|---|---|
| QSPECAO | Accuracy | Analysis of differences between observed and expected results of external QC Samples. |
| QSPECZ | Intralab precision | Comparison of results of laboratory-generated duplicate samples. |
| SPREPD | Intralab precision | Comparison of results of duplicate samples supplied by the Sample Bank. |
| SPREP | Interlab precision | Analysis of results of triplicate samples supplied by the Sample Bank. |

The QSPECAO program, designed to measure analysis accuracy, analyzed the differences between observed and expected concentrations for each pollutant reported for each external QC sample (as reported on "AO" cards). Input to the program was a file of validated (or verified) data which had been re-formatted to card-image records. This is illustrated in Figure 8.13. QSPECAO searched through the card-image file for all data submitted on AO cards, and reported these in a list of individual pairs. For each pollutant in each sample, the following information was listed:

- Sample ID
- Laboratory
- Pollutant name and code
- Observed concentration
- Expected concentration
- Difference between observed and expected concentrations.

Pollutants with zero values for either the observed concentration or the expected concentration were listed separately; they were not included in the list of pairs or in the subsequent analysis of the AO data.

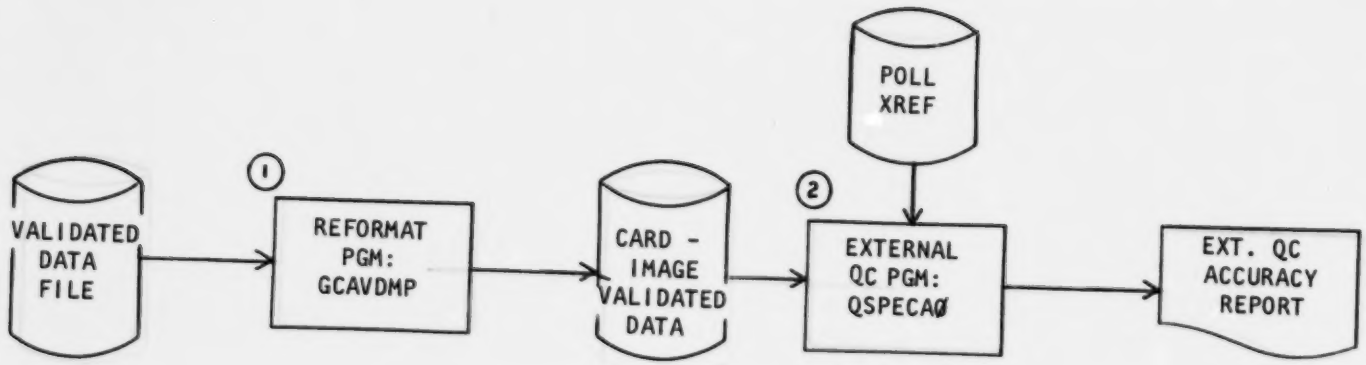


Figure 8.13. Data flow for external QC accuracy report.

The second part of the QSPECA0 report was a statistical analysis of external QC results for each medium, by laboratory and pollutant. Information listed for each such combination included:

- Laboratory
- Pollutant name and code
- Number of observations
- Mean difference between observed and expected concentrations
- Standard deviation
- Upper and lower 95 percent probability limits
- Upper and lower 95 percent confidence limits

The operation of the QSPECZ program, which compared the analysis results of laboratory-generated duplicate samples, was similar to the operation of the LCQC2 program, which performed these analyses on the raw data file. The data flow for the QSPECZ program is shown in Figure 8.14. Like the QSPECA0 program, the QSPECZ program operated on a file of validated data which had been reformatted into card-image records. The program searched through the file to identify samples with ID numbers beginning with "Z," and printed a listing of the observed concentrations of each pollutant found in the Z sample and its mate. Information listed included:

- Original Sample ID
- Laboratory
- Pollutant code
- Observed concentration for original sample
- Observed concentration for duplicate aliquot (Z sample)
- Difference between the two observed concentrations.

Entries were made in the listing only if a quantified (non-zero) concentration was reported for at least one member of the pair.

The program then performed a statistical analysis on these results, and generated a report which was summarized for each medium by laboratory and pollutant. Information listed for each such combination included:

- Laboratory
- Pollutant name and code

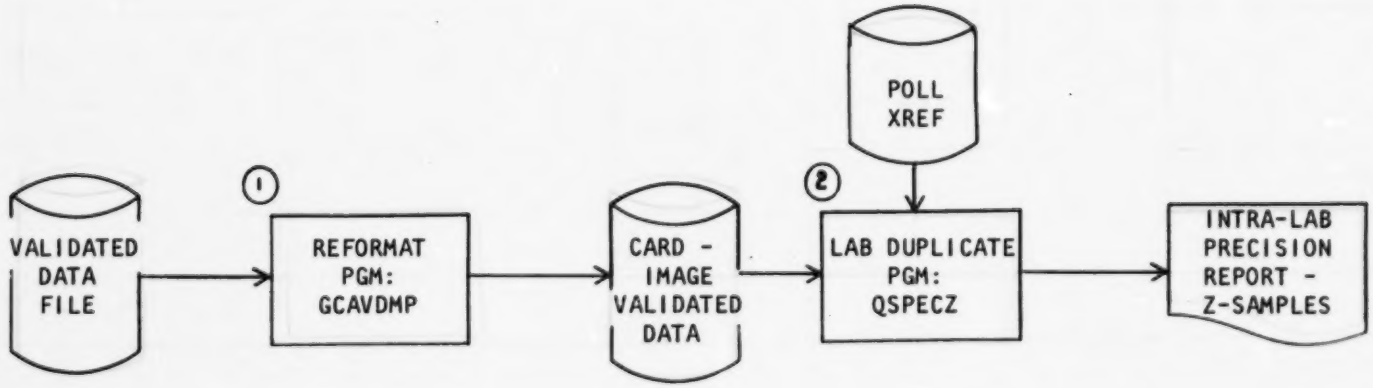


Figure 8.14. Data flow for intralab precision report for laboratory-generated (Z) samples.

- Number of observations
- Mean difference of concentrations
- 95 percent probability limits
- Standard deviation divided by 2.

The SPREPD program was also designed to measure intralab precision, but in this case the measurements were based on duplicate samples supplied by the Sample Bank, rather than on laboratory-generated duplicates. The Sample ID numbers of each pair of duplicates were provided to the SPREPD program on the QC Cross-Reference Cards (Q-Cards). These cards, which had been prepared by the Sample Bank, included all pairs of duplicates in the duplicate program, and the pair of each samples sent to the same laboratory during the triplicate program. The data flow for the SPREPD program is shown in Figure 8.15.

The SPREPD program worked directly on the validated (or verified) data file, searching through the file to identify each of the samples specified in the "Q-Cards" file. One part of the report generated by this program listed the observed concentration of each pollutant found in each pair of duplicates. Each entry in this list contained the following information:

- Laboratory
- Sample ID of each sample in pair
- Pollutant code
- Observed concentration for each member of the pair
- Difference between the two observed concentrations.

A statistical analysis of these results was performed, and a report was generated which summarized findings for each medium by laboratory and pollutant. This report was identical in format to that of the statistical analysis report of the QSPECZ program.

The final QA/QC program which was run on the verified or validated data file was the SPREP program, which was designed to measure interlab precision. Samples involved in this measurement were generated by the Sample Bank's triplicate sample program. Each set of triplicates included one sample which was sent to an EPA laboratory for analysis, and two samples which were sent to the same sub-contractor laboratory. Triplicates were identified to the SPREP program through the QC Cross-Reference cards file. The data flow for the SPREP program, which worked directly on the validated (or verified) data file, is shown in Figure 8.16.

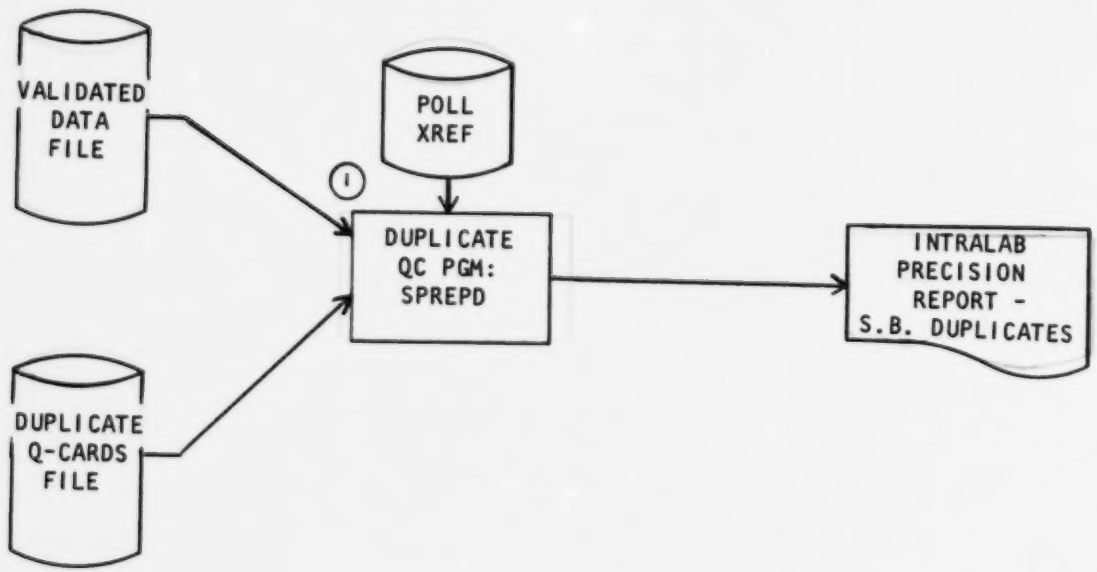


Figure 8.15. Data flow for intralab precision report for duplicates supplied by Sample Bank.



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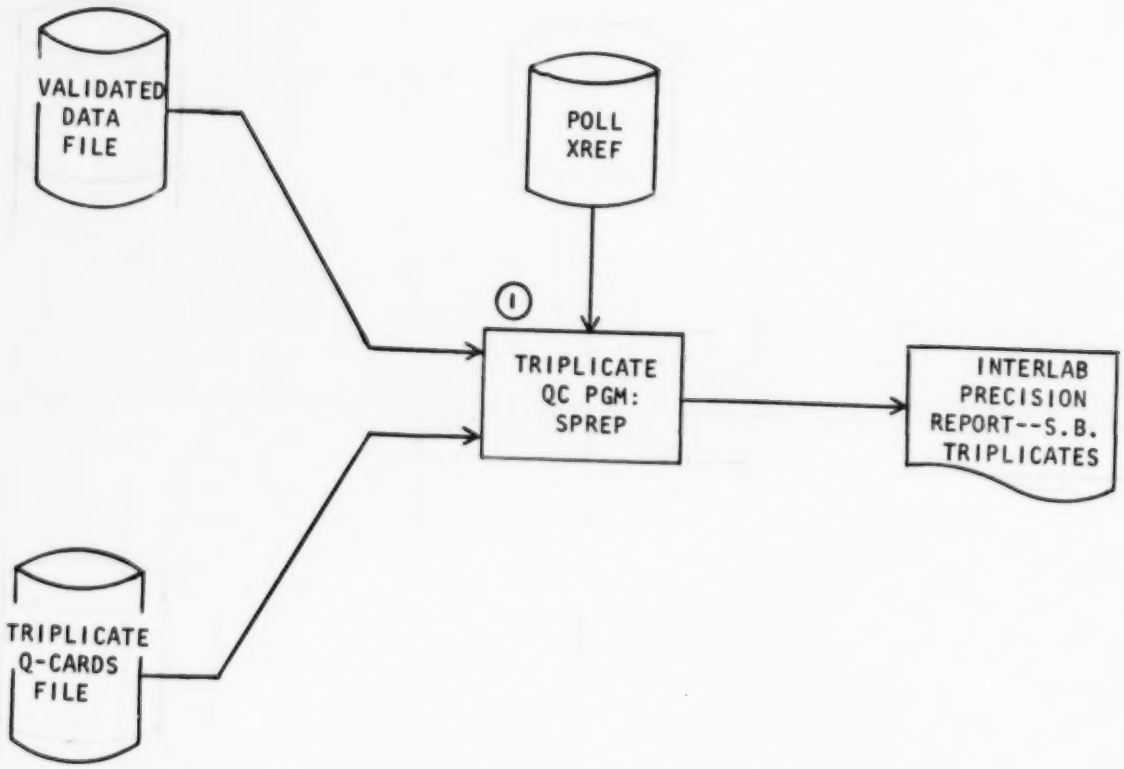


Figure 8.16. Data flow for interlab precision report for triplicates supplied by Sample Bank.

Three types of reports were generated by the SPREP program. One was a listing of individual pairs, with a separate entry in the list for each of the two sets of pairs comprising the set of triplicates. (The EPA sample and one subcontract lab sample formed one pair; the EPA sample and the other subcontract lab sample formed the second pair). Each entry in the listing contained the following information:

- Subcontract laboratory
- Subcontract lab Sample ID
- EPA Sample ID
- Pollutant code
- Concentration of subcontract sample
- Concentration of EPA sample
- Difference between subcontract and EPA concentrations
- Identification of set ("Set 1" or "Set 2").

The second SPREP report was a summary of a statistical analysis by medium, lab, and pollutant, in which the findings were reported separately for each set of pairs. The following information was given in each entry:

- Subcontract laboratory
- Pollutant name and code
- For Set 1:
  - number of observations
  - mean difference between concentrations
  - standard deviation
- For Set 2:
  - number of observations
  - mean difference between concentrations
  - standard deviation.

The final part of the SPREP report presented the results of a statistical analysis by medium, lab, and pollutant, in which the findings for the two sets

of pairs in each set of triplicates were combined, giving a pooled estimate of interlab precision. The following information was given for each entry in the listing:

- Subcontractor name and code
- Pollutant name and code
- Number of observations in Set 1
- Number of observations in Set 2
- Mean difference between the mean differences of the separate sets
- Standard deviation
- Control limits.

Appendix I provides a listing of the GCA Love Canal Software utilized in the Data Management Segment of the study.